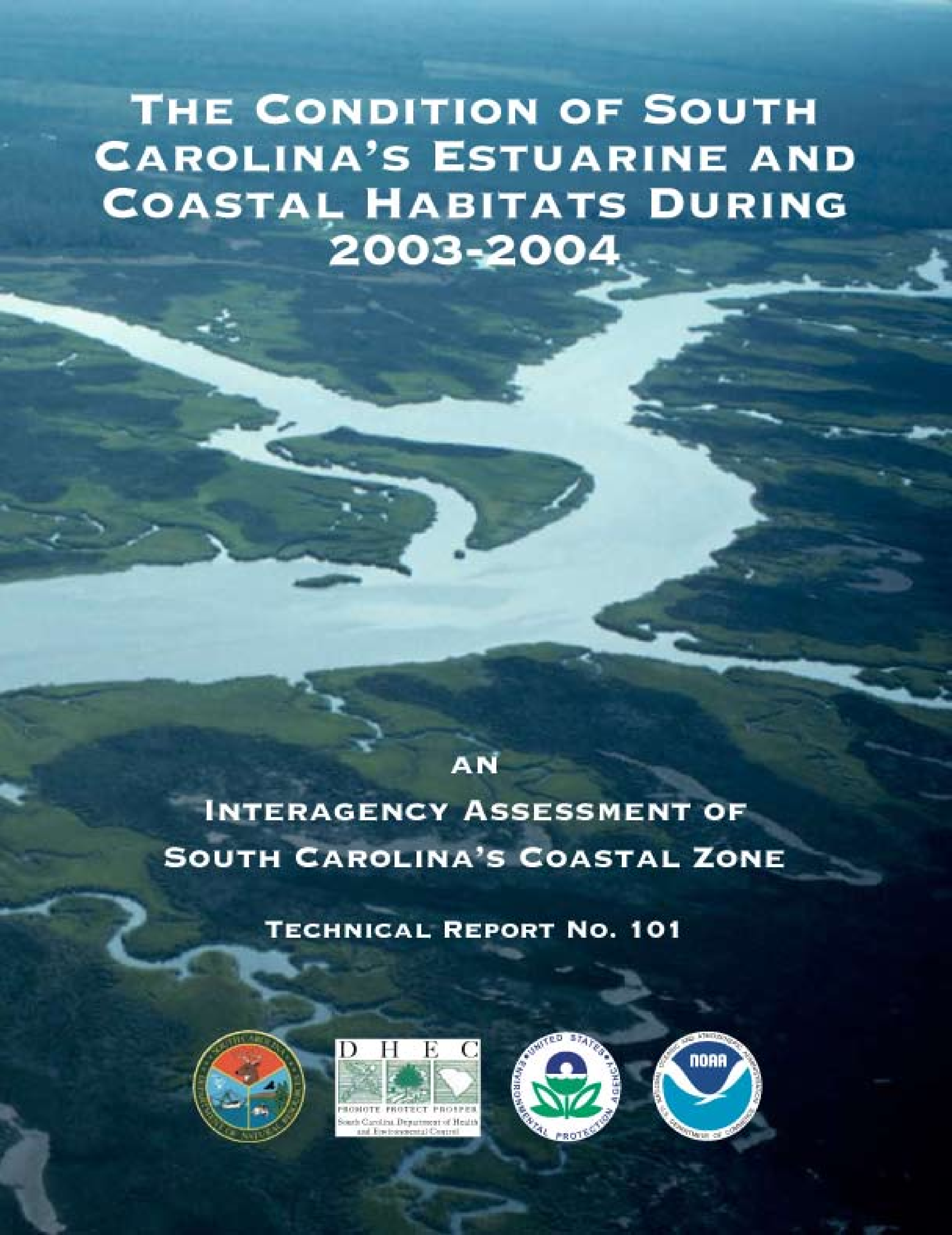

The Condition of South Carolina's Estuarine and Coastal Habitats During 2003-2004

An Interagency Assessment of South Carolina's Coastal Zone

Technical Report No. 101

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South Carolina Department of Health and Environmental Control

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The Condition of South Carolina's Estuarine and Coastal Habitats During 2003-2004

Technical Report

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Cover photo courtesy of South Carolina Department of Natural Resources photographer Phillip Jones

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1. INTRODUCTION

South Carolina's coastal zone includes a variety of sensitive habitats that serve as critical nursery areas for most of the state's commercial and recreational fishery resources. The annual economic impact of the state's saltwater recreational and commercial fisheries alone exceeds 650 million dollars (SCDNR, unpublished). Additionally, South Carolina's coastal zone is a major attraction to both the citizens of the state and out-of-state visitors, who contribute more than 14 billion dollars in travel and tourism activity to the state annually (World Travel and Tourism Council, 2001). As with most coastal states, population growth in the coastal counties has been rapidly increasing in recent years, with more than 1.04 million people estimated to be living in the eight coastal counties in 2004 (SC Budget and Control Board, 2005). This number is expected to increase another 30% by 2025. The associated development of housing, roads, and commercial and industrial infrastructure, combined with increased recreational utilization of our coastal waters, will result in an escalating potential for serious impacts to South Carolina's coastal habitats.

The South Carolina Estuarine and Coastal Assessment Program (SCECAP) was established in 1999 to begin evaluating the overall health of the state's estuarine habitats on a periodic basis using a combination of water quality, sediment quality, and biotic condition measures. This collaborative program involves the Department of Natural Resources (SCDNR) and the Department of Health and Environmental Control (SCDHEC) as the two lead state agencies, as well as the National Atmospheric and Oceanic Administration (NOAA) laboratories located in Charleston (Center for Coastal Environmental Health and Biomolecular Research and the Hollings Marine Laboratory) and the U.S. Environmental Protection Agency (USEPA) Gulf Ecology Division in Gulf Breeze, FL. SCECAP represents an expansion of ongoing monitoring programs being conducted by both the state and federal agencies and ranks among the first in the country to apply a comprehensive, ecosystem-based assessment approach for evaluating coastal habitat condition. The USEPA has implemented a similar approach at the national level through its National Coastal Assessment Program (NCA) and has used those data in collaboration with other federal agencies and data sources to prepare two National Coastal Condition Reports (USEPA, 2001, 2004). However, many of the parameters and thresholds used for the national report are not necessarily appropriate for South Carolina, and the program is providing regional assessments that are not specific to any one state. Additionally, the SCECAP initiative collects additional data parameters that are not collected by NCA.

There are several specific, yet critical, attributes of the SCECAP initiative that set it apart from other ongoing monitoring programs being conducted in South Carolina by SCDHEC (primarily for water quality) and SCDNR (primarily for fishery stock assessments). These include: (1) sampling sites throughout the coastal zone using a random, probability-based approach that complements both agencies' ongoing programs involving fixed station monitoring networks, (2) using integrated measures of environmental and biological condition that provide a more complete evaluation of overall habitat quality, and (3) monitoring tidal creek habitats in addition to the larger open water bodies that have been sampled traditionally by both agencies. Component 3 is of particular importance since tidal creek habitats serve as important nursery areas for most of the state's economically valuable species and often represent the first point of entry for runoff from upland areas. Thus, tidal creek systems can provide an early indication of anthropogenic stress (Holland *et al.*, 2004; Sanger *et al.*, 1999a, b; Lerberg *et al.*, 2000; Van Dolah *et al.*, 2000; 2002a, b; 2004a).

This technical report is the third in a series of reports describing the status of South Carolina's estuarine habitats. Findings from the 2003-2004 sampling period are described and compared with previous surveys conducted in 1999-2000 and 2001-2002 (Van Dolah *et al.,* 2002a, 2004a). The 2003-2004 survey period represents the first survey conducted since the inception of the program that encompasses more typical rainfall patterns as compared to the drought conditions experienced from 1999-2002.

2. METHODS

The sampling and analytical methods used for SCECAP are fully described in the first SCECAP report covering the 1999-2000 survey period (Van Dolah *et. al.*, 2002a). This report and associated data can also be viewed and downloaded from the SCDNR's SCECAP web site (http://www.dnr.sc.gov/marine/scecap/). Descriptions of the SCECAP sampling design, measured parameters, and general analytical approach are summarized in the following sections. In general, this program utilizes methods consistent with SCDHEC's water quality monitoring programs (SCDHEC, 2001) and the USEPA's NCA Program (http://www.epa.gov/emap/nca/index.html).

2.1. Sampling Design

Approximately 60 stations were selected for sampling each year within South Carolina's coastal zone extending from the Little River Inlet at the South Carolina - North Carolina border to the Savannah River at the South Carolina - Georgia border and extending from the saltwater-freshwater interface to near the mouth of each estuarine drainage basin. Approximately half of the stations were located in tidal creeks, and the other half were located in the larger open water bodies that form South Carolina's tidal rivers, bays, and sounds. Tidal creeks are defined as those estuarine water bodies less than 100 m wide from marsh bank to marsh bank. Portions of the state's coastal waters that are too shallow to sample at low tide, such as the headwater portions of tidal creeks with less than 1 m of water at low tide, intertidal mud flats, and vegetated salt marsh, were excluded from the station selection process. All stations had to have a minimum water depth of 1 m since some sampling components required visits that could not be limited by tidal stage, and other sampling components were limited to periods within three hours of low tide. Coastal maps developed for SCECAP to define the boundaries of tidal creeks and open water habitats suitable for sampling by this program indicate that approximately 17% of the state's estuarine waters by surface area represents creek habitat, and the remaining 83% represents the larger open water areas.

A typical tidal creek habitat in South Carolina.

Stations within each habitat type were selected using a probability-based, random tessellation, stratified sampling design (Stevens, 1997; Stevens and Olsen, 1999), with new station locations assigned each year. Actual sampling locations were recorded using the Global Positioning System (GPS). Each year, a new set of random stations was generated.

All stations were sampled once during the summer (late June through August). The summer period was selected since it represents a period when some water quality variables may be limiting to biota, and it is a period when many of the fish and crustacean species of concern are utilizing the estuary for nursery habitat. Most of the measures were collected within a 2-3 hr time period; however, the water quality data also includes time-series measures collected over a 25-hr time period. Approximately 30 of the sites sampled each year (15 tidal creek and 15 open water) were also sampled monthly by SCDHEC for most water quality measures, except dissolved nutrients and total suspended solids (TSS), to collect a full 12 months of data for each site. The results of that sampling effort are compared to the summer-only integrated index of water quality condition for the state in order to assess the validity of the summer assessment relative to year-round water quality measurements (See Box 3.2.2).

2.2. Water Quality Measurements

Water quality measurements and samples were generally collected prior to deployment of other sampling gear to ensure that bottom disturbance did not affect these measures. Near-surface (0.3 m depth), mid-water, and near-bottom (0.3 m above bottom) instantaneous measurements of dissolved oxygen, salinity, and temperature were collected using Yellow Springs Instrument (YSI) Inc. Model 85 water quality meters. Near-surface measures of pH were collected using a pHep® 3 field microprocessor meter. More extensive time-profile measurements of all four parameters were obtained from the near-bottom waters of each site using YSI Model 6920 multiprobes logging at 15 min intervals for a minimum of 25 hrs to assess conditions over two full tidal cycles representing both day and night conditions.

Water quality samples included near-surface measures of nitrogen (including ammonia, nitrate/nitrite, total Kjeldahl nitrogen (TKN), and total nitrogen (TN)), total phosphorus (TP), total organic carbon (TOC), total suspended solids (TSS), turbidity, five-day biochemical oxygen demand (BOD_5), chlorophyll-*a*, and fecal coliform bacteria concentrations. Near-surface measures of dissolved nutrients, including ammonia, inorganic nitrogen (DIN), organic nitrogen (DON), inorganic phosphorus (orthophosphate or OP), organic phosphorous (DOP), and silica (DS), were also collected. All samples were collected by inserting pre-cleaned water bottles to a depth of 0.3 m inverting and then filling the bottle directly at that depth. Water samples collected for dissolved nutrient quantification were filtered in the field through a 0.45 µm pore cellulose acetate filter. The bottles were then stored on ice until they were returned to the laboratory for further processing. Total nutrients, TOC, total alkalinity, TSS, turbidity, BOD_5, chlorophyll-*a*, and fecal coliform bacteria samples were processed by SCDHEC using standardized procedures (SCDHEC, 1998b, 2001, 2005). Dissolved nutrients were processed through the University of South Carolina using a Technicon AutoAnalyzer and standardized procedures described by Lewitus *et al.* (2003). DON and DOP were calculated by subtracting total inorganic from total dissolved N or P, measured by the persulfate oxidation technique (D'Elia *et al.,* 1977).

2.3. Biological and Sediment Sampling

Bottom sediment samples were collected at each station using a stainless steel 0.04 m^2 Young grab deployed from an anchored boat. The boat was repositioned between each sample to ensure that the same bottom was not sampled twice and to spread the samples over a 10-20 m^2 bottom area. The grab was thoroughly cleaned prior to field sampling and rinsed with isopropyl alcohol between stations. Three of the grab samples were washed through a 0.5 mm sieve to collect the benthic invertebrate fauna which were then preserved in a 10% buffered formalin-seawater solution containing rose bengal stain. The surficial sediments (upper 3 cm) of the remaining grab samples were homogenized on site and placed in pre-cleaned bottles for analysis of sediment composition, contaminants, and sediment toxicity. All sediment samples were kept on ice while in the field and then stored either at 4^{o}C (toxicity, porewater) or frozen (contaminants, sediment composition, TOC) until analyzed.

The Young "grab" is used to collect sediments and benthic fauna. Photo credit: R. Van Dolah

Particle size analyses were performed using a modification of the pipette method described by Plumb (1981). Pore water ammonia was measured using a Hach Model 700 colorimeter and TOC was measured on a Perkin Elmer Model 2400 CHNS Analyzer.

Contaminants measured in the sediments included 22 metals, 25 polycyclic aromatic hydrocarbons (PAHs), 79 polychlorinated biphenyls (PCBs), 13 polybrominated diphenyl ethers (PBDEs), and 21 pesticides. All contaminants were analyzed by the NOAA-NOS Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) using procedures similar to those described by Krahn *et al.* (1988), Fortner *et al.* (1996), Kucklick *et al*. (1997), and Long *et al.* (1997).

Sediment toxicity was measured using three bioassays. They included: (1) the Microtox® assay using a photoluminescent bacterium, *Vibrio fischeri*, and protocols described by the Microbics Corporation (1992), (2) a 7-day juvenile clam growth assay using *Mercenaria mercenaria* and protocols described by Ringwood and Keppler (1998), and (3) a 10-day whole sediment amphipod assay using *Ampelisca abdita* and protocols described by ASTM (1993). Toxicity in the Microtox® assay was based on criteria described by Ringwood *et al.* (1997; citerion #6: toxic when scores of < 0.5 if silt/clay < 20% and scores of < 0.2 if silt/clay > 20%). For the clam assay, sediments were considered toxic if growth (dry weight) was < 80% of that observed in control sediments and there was a statistically significant difference ($p < 0.05$). For the amphipod assay, sediments were considered toxic if survival was < 80% of that observed in control sediments and the difference was statistically significant ($p < 0.05$).

Water samples for phytoplankton community analysis were collected from near-surface water concurrently with water quality samples. Fresh samples were examined under a microscope for species identifications, and subsamples were filtered and analyzed for taxon-specific biomass determination. While chlorophyll-*a* is a useful surrogate for computing phytoplankton biomass, it must be coupled with species-specific pigment ratios to yield information about community composition. This analytical method, CHEMTAX, is a matrix factorization program that generates a profile of the community based on the pigment ratio detected in the water sample using High Pressure Liquid Chromatography (HPLC) (Lewitus *et al*., 2005). HPLC data can be used to calculate the portion of the phytoplankton community attributable to individual taxonomic groups. It is not as refined as counting individual species of phytoplankton, but it allows for rapid and accurate quantification of biomass of relevant groups of phytoplankton. Using these pigment ratios, the community can be divided into species which are typically present in a pristine estuarine environment (diatoms, mixed flagellates) versus those which are abundant in nutrient-rich seawater (dinoflagellates, raphidophytes) or nutrient-rich freshwater inflows (cyanobacteria).

Two of the three grab samples collected to assess benthic invertebrate community composition were sorted in the laboratory to separate organisms from the sediment remaining in the sample. The third grab sample was held in reserve. All organisms from the two grabs were identified to the species level or to the lowest practical taxonomic level possible if the specimen was damaged or too immature for accurate identification. A reference collection of all benthic species collected for this program is being maintained at the SCDNR Marine Resources Research Institute.

Fish and large crustaceans (primarily penaeid shrimp and blue crabs) were collected at each site following benthic sampling to evaluate near-bottom community composition. Two replicate tows were made at each site using a 4-seam trawl (5.5 m foot rope, 4.6 m head rope and 1.9 cm bar mesh throughout). Trawl tow lengths were standardized to 0.5 km for open water sites and 0.25 km for creek sites. Tows were made only during daylight hours with the current, and boat speed was standardized as much as possible. Tows made in tidal creeks were limited to periods when the marsh was not flooded (approx. 3 hrs $\pm$ mean low water). This limitation was also generally applied to open water sites. Catches were sorted to lowest practical taxonomic level, counted, and checked for gross pathologies, deformities or external parasites. All organisms were measured to the nearest centimeter. When more than 25 individuals of a species were collected, the species was sub-sampled. Mean abundance of finfish and

Trawls are used to sample mobile fish and crustaceans. Photo credit: R.F. Van Dolah crustaceans were corrected for the total area swept by the two trawls using the formula described by Krebs (1972).

Fish tissue samples for contaminant analyses were obtained from trawls. Targeted species included spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*). Silver perch (*Bairdiella chrysoura*) or weakfish (*Cynoscion regalis*) were collected if they were present when the target species were not. All fish samples were wrapped in foil and stored on ice in plastic bags until they could be frozen in the laboratory. Entire fish were then rinsed and homogenized in a stainless steel blender. Extraction and analytical procedures were similar to those described for sediments.

2.4. Habitat Evaluation

Observations were made at each site prior to departure to document the presence of litter (within the limits of the trawled area) and to note the proximity of the site to urban/suburban development or industrial development.

2.5. Quality Assurance

SCECAP protocols include rigorous quality assurance and quality control guidelines for all aspects of the program to ensure that the database is of high quality. A copy of the Quality Assurance Project Plan is maintained at the SCDNR Marine Resources Research Institute and has been approved by the USEPA NCA Program.

2.6. Data Analyses

Comparisons of most water quality, sediment quality and biological measures were completed using standard parametric tests or non-parametric tests where the values could not be transformed to meet parametric test assumptions. Two stations (RO046286 and RT042266) were not included in the comparisons, since these sites represented special study sites selected to add stations in the Charleston Harbor estuary. Comparisons of measurements collected in tidal creek versus open water habitats were conducted using a t-test or non-parametric Mann-Whitney U test. Comparisons involving more than two station groups or multiple years were generally completed using ANOVA or Kruskal-Wallis tests. Data from 2003 and 2004 were generally pooled within each habitat type to calculate the current condition of and temporal trends in most individuals measures. Data from the two years were separated within each habitat type to examine changes in integrated water quality and sediment quality scores, benthic biological condition and overall habitat quality as well as for several individual measures of particular concern.

Use of the probability-based sampling design provided an opportunity to statistically estimate, with confidence limits, the proportion of South Carolina's overall creek and open water habitat that falls within ranges of values that were selected based either on (1) state water quality criteria, (2) historical measurements collected by SCDHEC from 1993-1997 in the state's larger open water bodies (SCDHEC, 1998a), or (3) other thresholds indicative of stress based on sediment chemistry or biological condition (Hyland *et al*., 1999; Van Dolah *et al.,* 1999). These estimates were obtained through analysis of the cumulative distribution function (CDF) using procedures described by Diaz-Ramos *et al*. (1996).

3. RESULTS AND DISCUSSION

Data obtained from the 2003-2004 survey are summarized in the following sections. More extensive data summaries are also available on the SCECAP web site (http://www.dnr.sc.gov/marine/scecap/) and are referenced in this report as "data online."

3.1. Station Array

The locations of the 60 sites sampled in 2003 and 2004 are provided in Figures 3.1.1 - 3.1.4 and Appendix 1. Tidal creek station numbers are designated by RT, and open water stations are designated by RO. As noted previously, the two supplemental sites sampled in 2004 to obtain additional data for the Charleston Harbor estuary (RO046286 and RT042266) are not included in the general analyses of state-wide condition, but the data are available online.

The average depth of open water sites sampled during the two-year period was 5.2 m and varied from approximately 1.2-14.0 m (Appendix 1, data online).

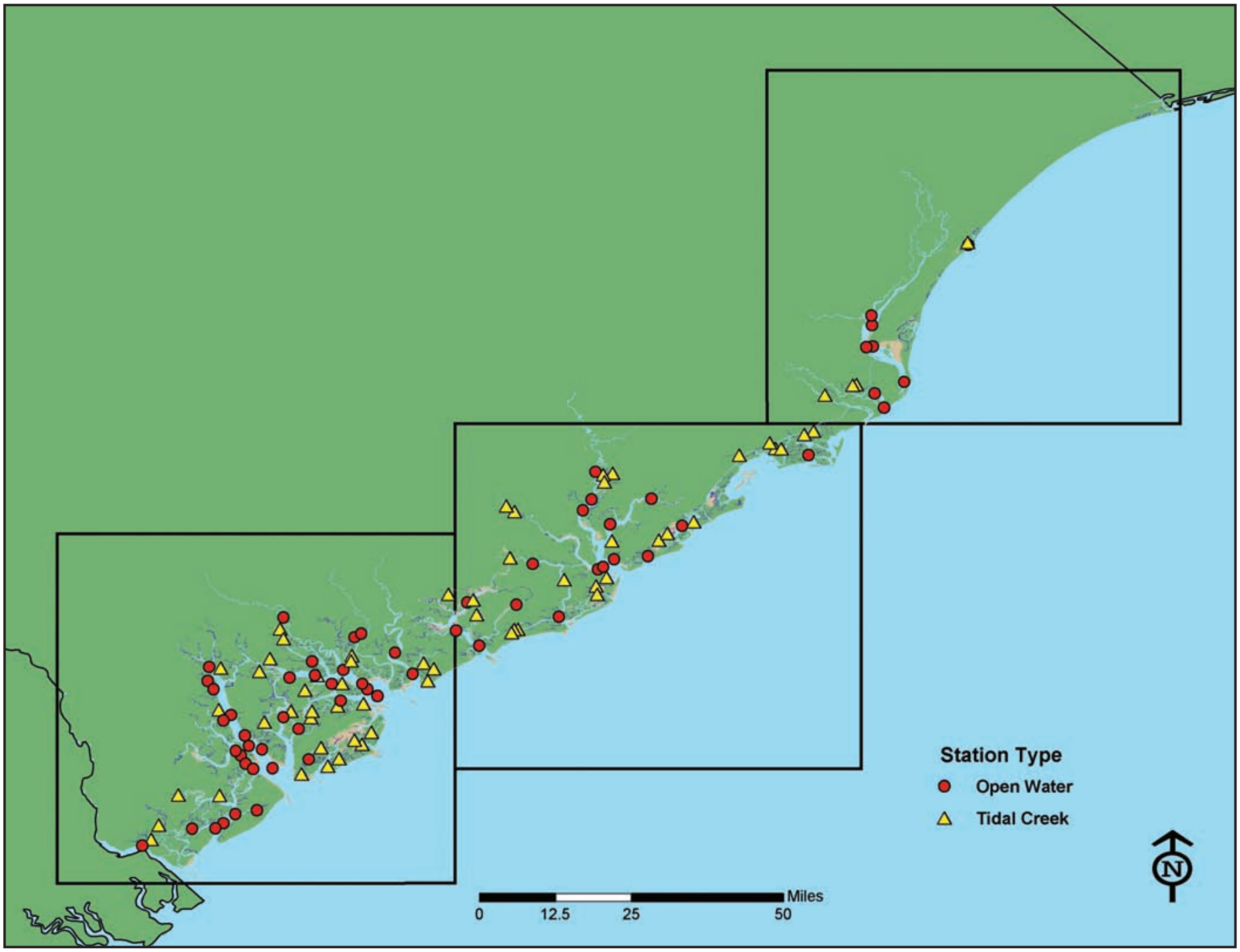


Figure 3.1.1. Distribution of open water and tidal creek stations sampled throughout South Carolina's coastal zone during 2003 - 2004 with northern, central and southern geographic regions outlined.

Average depth of the tidal creek sites was 2.5 m and varied from approximately 0.3 to 6.1 m. Only one site was substantially less than the 1 m minimum criteria due to unusual tidal conditions. Average depths and ranges were comparable to the previous survey periods (Van Dolah *et al*., 2002a, 2004a).

3.2. Water Quality

Although instantaneous measures of basic water quality variables (temperature, salinity, dissolved oxygen, pH) were obtained during the primary visit to each site, the continuous measures of these parameters from the 25-hr instrument deployments provide the most comprehensive information because they include numerous measures during both day and night over two complete tidal cycles. Therefore, these data are used as the primary data set in our analyses of these four water quality parameters. The other measures of water quality (total and dissolved nutrients, BOD_5, TSS, turbidity, TOC, total alkalinity, chlorophyll-*a*, and fecal coliform bacteria) obtained at each site represent instantaneous measures collected during the primary site visit.

State regulations 61-68 and 61-69 have been developed to protect the water quality of the state (SCDHEC, 2004). The water quality standards include numeric and narrative criteria that are used for setting permit limits on discharges to waters of the state, with

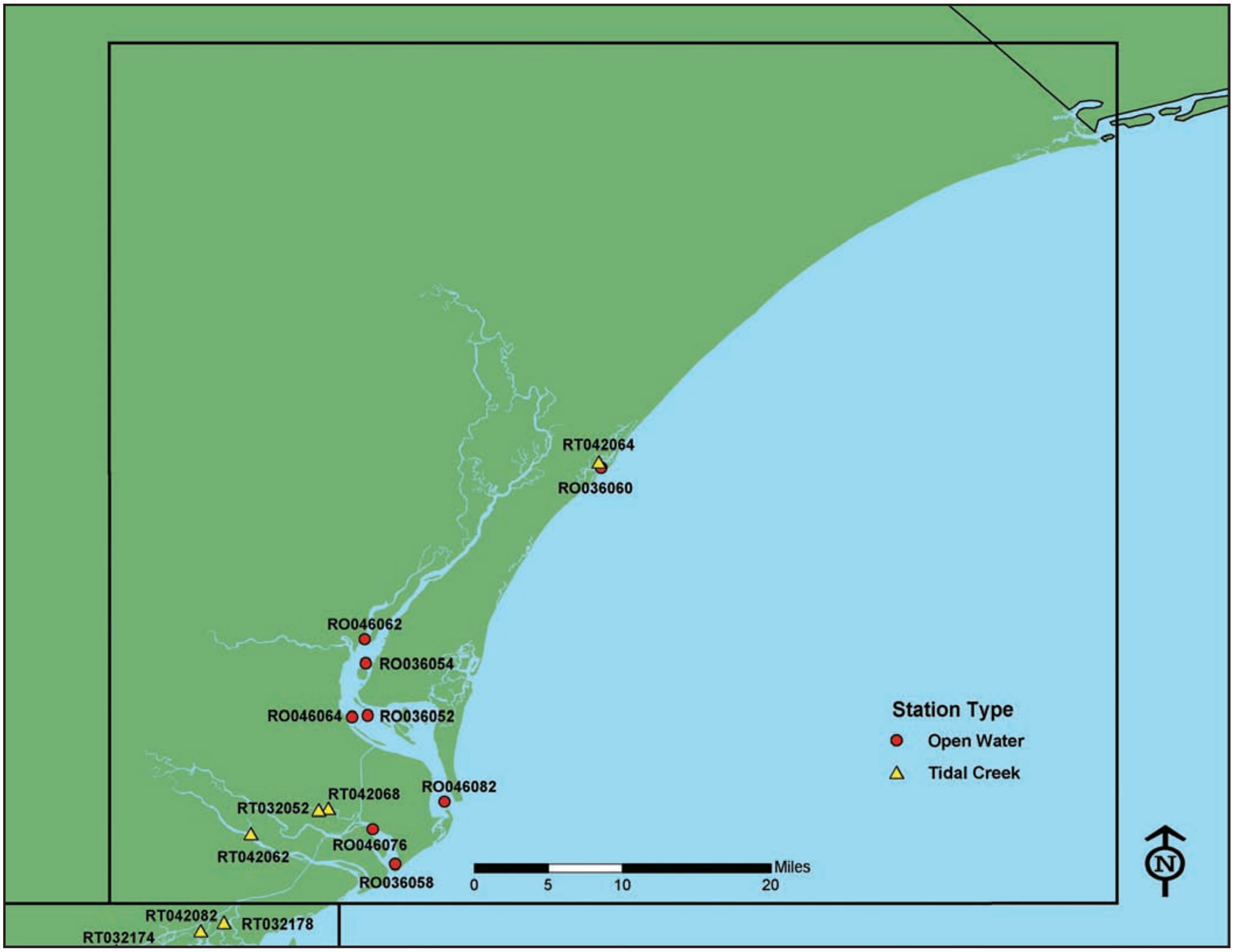


Figure 3.1.2. Distribution of open water and tidal creek stations sampled in the northern portion of the state during 2003 - 2004.

the intent of maintaining and improving surface waters "to a level to provide for the survival and propagation of a balanced indigenous aquatic community of flora and fauna and to provide for recreation in and on the water." Occasional short-term departures from these conditions will not automatically result in adverse effects to the biological community. The standards also recognize that deviations from these criteria may occur solely due to natural conditions and that the aquatic community is adapted to such conditions. In such circumstances, the variations do not represent standards violations, and critical conditions of the natural situation, e.g., low flow, high temperature, minimum dissolved oxygen, etc., are used as the basis of permit limits.

All data collected by SCECAP from field observations and water samples are related to water quality standards for the state's saltwater regions (SCDHEC, 2004) where possible. Because SCECAP samples are limited to a summer index period and generally do not include multiple samples over time, the summertime-only data are not appropriate for use in USEPA 303(d) or 305(b) reporting requirements. Additionally, only four water quality parameters have state water quality standards (dissolved oxygen, pH, turbidity, fecal coliform bacteria). For other parameters measured by SCECAP, values are compared to data compiled for a five-year period (1993-1997) by the SCDHEC Bureau of Water in their routine statewide Fixed Ambient Surface Water Monitoring Network

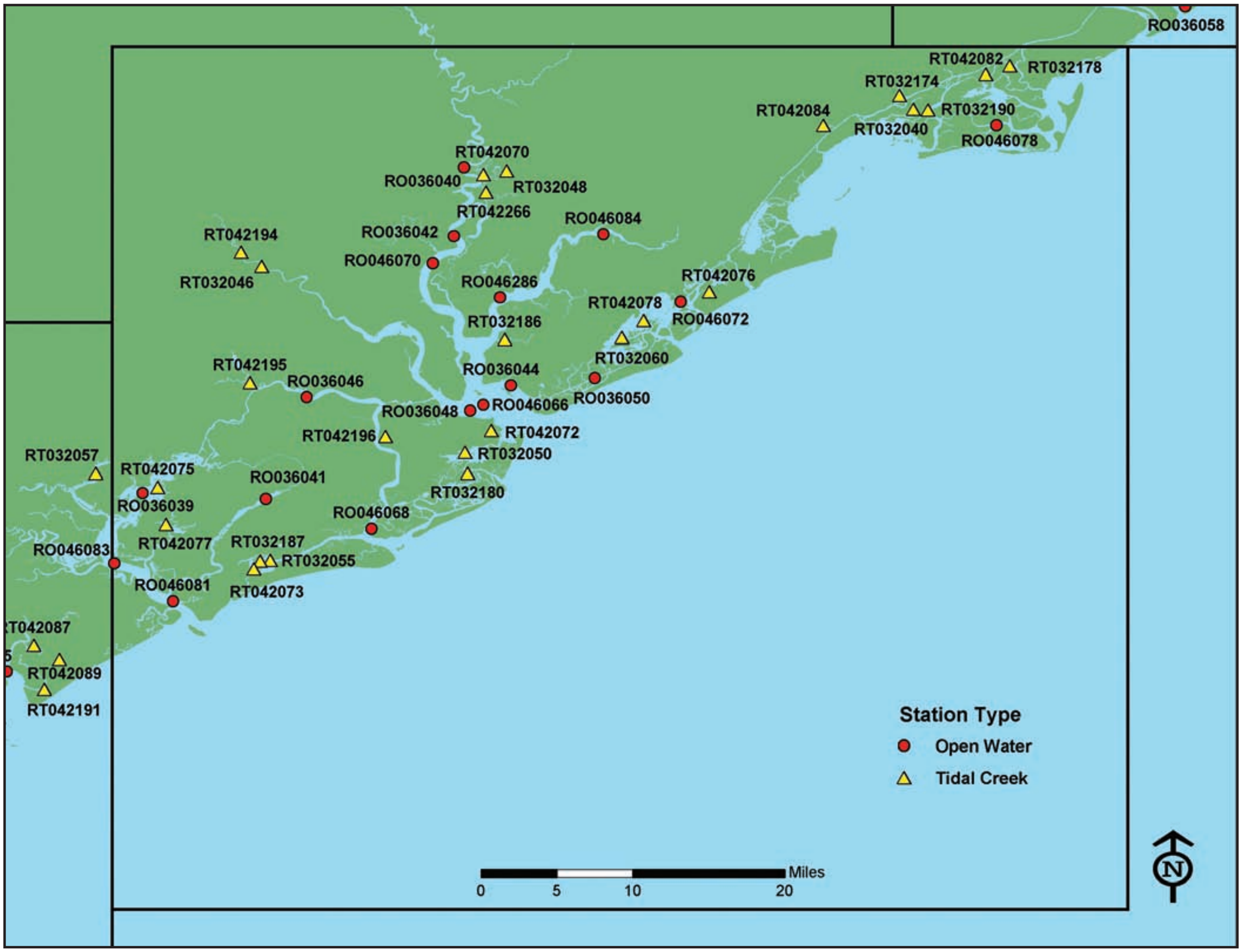


Figure 3.1.3. Distribution of open water and tidal creek stations sampled in the central portion of the state during 2003 – 2004.

(SCDHEC, 1998a). SCECAP criteria consider any value less than the 75th percentile of all 1993-1997 historical values measured (≥ method detection limit) in the state's saltwater habitats as evidence of normal (good) condition. Values exceeding the 75th percentile of the historical data are considered to be elevated (fair), and values exceeding the 90th percentile of all saltwater measures indicate high (poor) concentrations. The SCDHEC historical database on water quality was primarily obtained from larger open water bodies. Therefore, caution should be used in interpreting data obtained from tidal creek sites since high or low values observed for some parameters may represent "normal" conditions. Box 3.2.1 compares the 1993-1997 historical data to both the open water and tidal creek data collected from 1999-2004 by SCECAP. For some water quality variables, such as dissolved nutrients and chlorophyll-*a*, criteria or guidelines published in other reports are used for comparison of conditions (e.g. Bricker *et al.*, 1999; USEPA, 2004) since no appropriate historical data were available for South Carolina.

SCECAP collects many water quality variables that are either required for the NCA Program or for SCDHEC's assessment of state water quality condition for USEPA 303(d) or 305(b) reporting purposes. This technical report summarizes salinity and all water quality parameters that are used for the integrated measure of overall water quality. This report does not summarize temperature, TOC, BOD_5, dissolved nutrients, and alkalinity. Temperature data are primarily collected to relate with other water

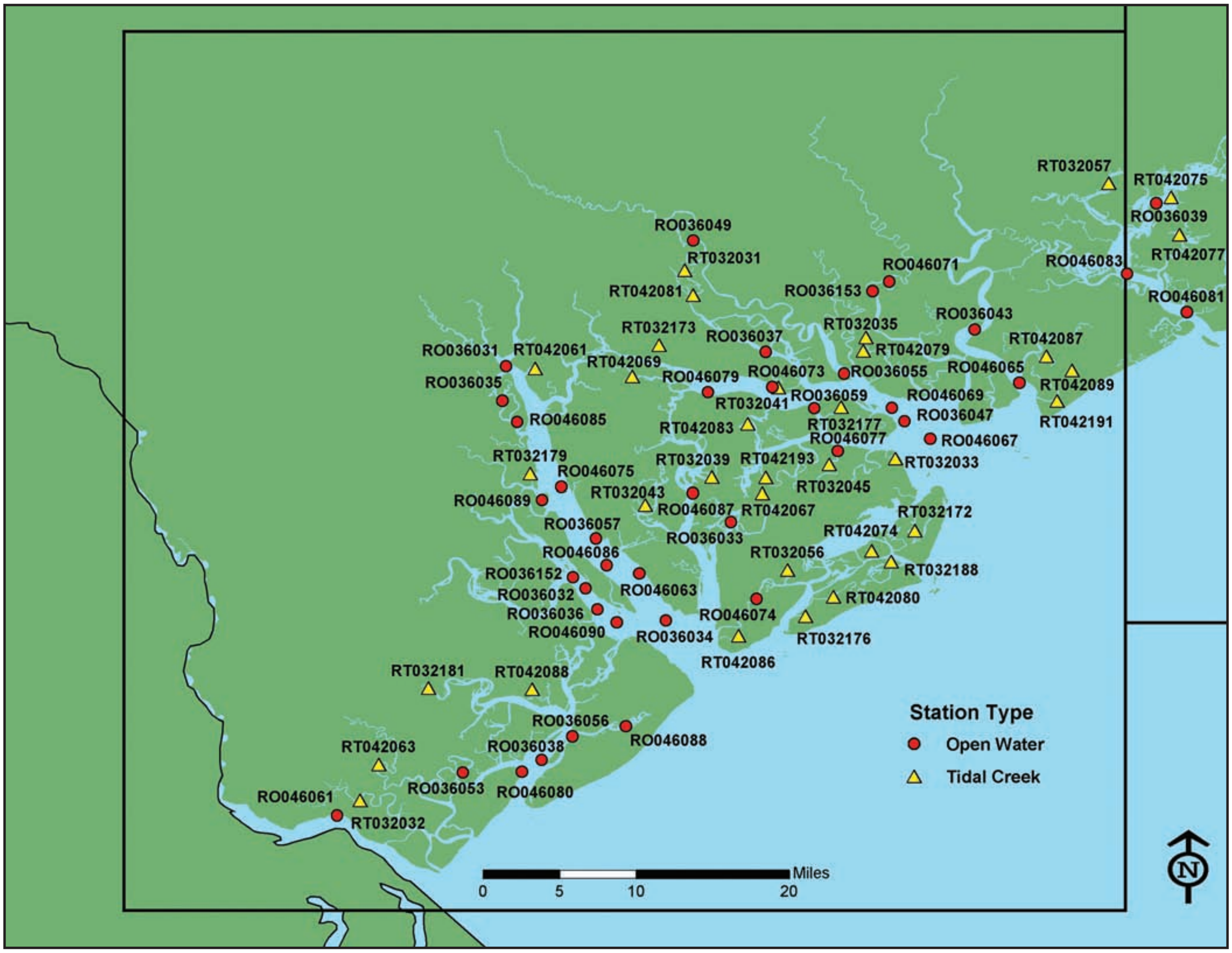


Figure 3.1.4. Distribution of open water and tidal creek stations sampled in the southern portion of the state during 2003 – 2004.

quality variables affected by this parameter. The other excluded parameters have no state standards for estuarine waters. Data on all parameters, reported or not, are provided on the SCECAP web site for those interested in acquiring the data.

Salinity

Salinity influences the distribution and diversity of many invertebrate and fish species and can be stressful to many organisms when large variations occur over short time periods. Mean bottom salinities of all sites sampled during the 2003-2004 survey were 23.5 ppt and 24.2 ppt in the tidal creek and open water habitats, respectively. This difference was not statistically significant ($p = 0.998$), but both means were lower than those observed in the previous two surveys conducted in 1999-2000 and 2001-2002. Additionally, the percentage of the state's estuarine waters that were considered to be oligohaline (≤ 5 ppt) or mesohaline (> 5 to < 18 ppt) was 28% and 29% for tidal creeks and open water habitat, respectively, compared to < 11% for either habitat in the previous two surveys (Figure 3.2.1). This reflects the effects of increased rainfall following a four year record drought. While greater rainfall might be expected to increase the mean range of salinities observed at the sites sampled over a 25-hr period, this was not observed. The average salinity ranges observed were 4.2 ppt among the tidal creek sites and 6.8 ppt among the open water sites, which were similar to the average ranges observed in previous survey periods (data online). However, three tidal creek sites (RT032178, RT042068, RT042084) and four open water sites (RO036043, RO036052, RO036058, RO046081) had salinity ranges ≥ 20 ppt, which may represent stressful conditions to many species. Until additional data are available, no criteria have been established by SCECAP to identify stressful conditions using salinity. The sites having these salinity ranges likely reflect the effects of major rainfall events that occurred just before or during our deployment of the datasondes.

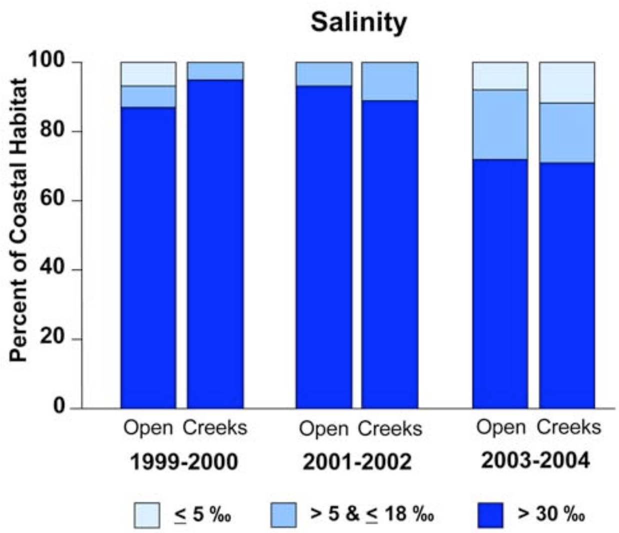


Figure 3.2.1. Comparison of the percent of the state's coastal habitat that represented various salinity ranges during the three survey periods conducted from 1999-2004.

The average difference between surface and bottom salinity measurements taken during the primary station visit was 0.3 ppt in tidal creeks and 0.9 ppt in open water areas. Only one tidal creek site had a difference > 5 ppt, and surface to bottom differences at the majority of creek sites were < 1 ppt (data online). This was also the case for open water stations, with only four stations having > 5 ppt variation in salinity.

Dissolved Oxygen

Low dissolved oxygen (DO) conditions can limit the distribution or survival of most estuarine biota, especially if these conditions persist for extended time periods (see Diaz and Rosenberg, 1995; USEPA, 2001 for reviews). Dissolved oxygen criteria established by the SCDHEC for "Shellfish Harvesting Waters" (SFH) and Class SA saltwaters are a daily average not less than 5.0 mg/L with no values less than 4.0 mg/L (SCDHEC, 2004). Class SB waters should have no values less than 4.0 mg/L. The SCECAP program was designed to sample only during a summer index period when DO levels are expected to be at their lowest. As a result, it was expected that DO measurements collected in this program probably represent short-term worst-case conditions that may not reflect conditions during other seasons or longer time-averaging periods. Although that expected pattern was not reflected in our comparison of summer only versus 12-month measurements of dissolved oxygen (Box 3.2.2), SCDHEC requires year-round monthly measurements for their regulatory purposes. Therefore SCECAP data should be used only to identify coastal habitats where DO levels may be limiting. Based on the state water quality standards, mean or instantaneous DO concentrations > 4 mg/L are considered to be good for summer time periods, values < 4 mg/L and ≥ 3 mg/L are considered to be fair (i.e., contravenes one portion of the state standards), and average or instantaneous measures < 3 mg/L are considered to be poor and potentially stressful to many invertebrate and fish species.

The average bottom DO concentration at the open water stations during the 2003-2004 survey was 5.2 mg/L, with approximately 90% of the state's open water habitat having an average DO > 4.0 mg/L based on the 25-hr instrument deployments (Figure 3.2.2; data online). These conditions were very comparable to DO conditions observed in the previous survey period (Van Dolah *et al*., 2004a). Only two open water sites (representing approximately 3% of the state's open water habitat) had an average DO < 3.0 mg/L (RO036043, RO046076). These sites were in the South Edisto River and the North Santee River, respectively (Appendix 2). The latter site also had an instantaneous bottom DO of 2.3 mg/L, with a surface water DO concentration of 3.1 mg/L.

The average bottom DO concentration observed at tidal creek sites was 4.8 mg/L, with 85% of this habitat having an average DO value > 4.0 mg/L. The average DO value observed among the tidal creek sites was significantly lower than the average DO observed among the open water sites ($p = 0.003$), but this difference is not likely to be biologically meaningful since the average difference was < 0.5 mg/L and both

Box 3.2.1 Comparison of SCECAP Data to Historical SCDHEC Data

Many of the thresholds derived for SCECAP for water quality parameters that don't have state standards were based on a historical database created by SCDHEC (1998a) from 1993-1997. This database predominantly represents conditions found in the larger open water habitats that have been routinely sampled by SCDHEC in their ambient stream monitoring network. Thus, there has been concern that the thresholds may not be as appropriate for tidal creek habitats. Now that six years of data are available through SCECAP, we have computed the 75th and 90th percentile thresholds for a variety of water quality variables monitored through this program. The results suggest that some of the thresholds should be re-considered, but many are very close to the historical thresholds. Those subject to reconsideration include TN, TOC, and turbidity. Even in those cases, there often does not appear to be enough of a difference between the tidal creek and open water thresholds to warrant consideration of separate thresholds for these variables, especially based on the method detection limits (MDL) which provides some indication of likely precision in these measurements. That is not the case for turbidity; however, SCDHEC has already established criteria (25 NTU) for this parameter.

Data Source	TN (mg/L)	TP (mg/L)	Chlorophyll-*a* (µg/L)	TOC (mg/L)	Turbidity (NTU)	BOD_5 (mg/L)
75th Percentiles:						
SCDHEC database (1993-1997)						
All Stations	0.95	0.09	Not measured	11.00	15.00	1.80
SCECAP Database (1999-2004)						
All Stations	0.73	0.10	12.00	8.30	20.50	1.90
Tidal Creek Stations	0.80	0.11	14.00	9.60	26.00	2.20
Open Water Stations	0.68	0.09	10.22	7.88	16.00	1.10
90th Percentiles:						
SCDHEC database (1993-1997)						
All Stations	1.29	0.17	Not Measured	16.00	25.00	2.60
SCECAP Database (1999-2004)						
All Stations	0.98	0.13	17.08	13.00	32.80	2.70
Tidal Creek Stations	0.98	0.14	21.11	14.00	39.80	3.10
Open Water Stations	0.95	0.11	14.52	12.00	24.00	2.40
Method Detection Limits (MDL)	0.10*	0.20		2.00	0.20	2.00

* Based on MDL for TKN, which is the least sensitive components of the TKN+NOx components used to estimate TN

Summary of the 75th and 90th percentile thresholds developed from the SCDHEC historical database currently being used by SCECAP, and the same thresholds based on six years of sampling by the program.

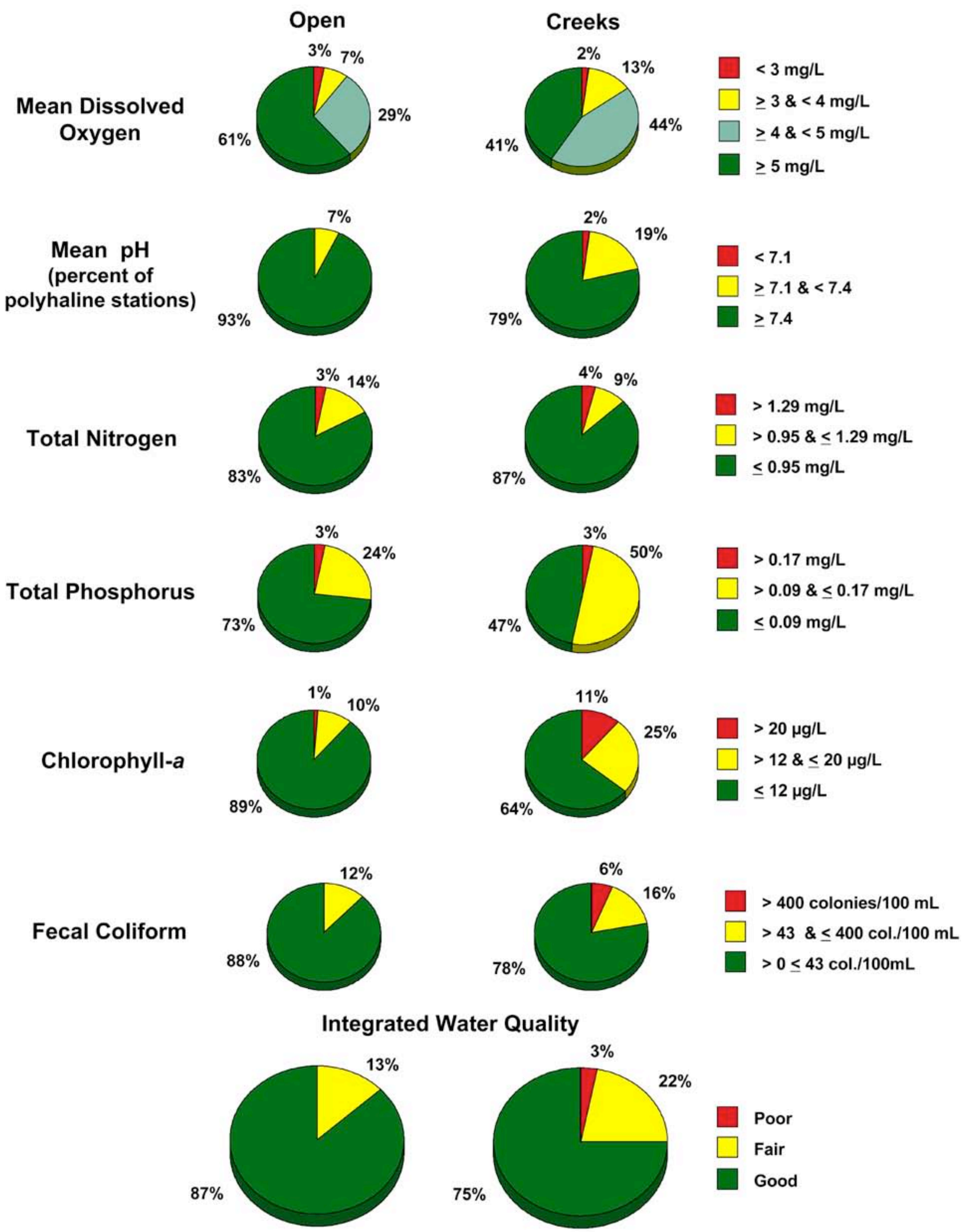


Figure 3.2.2. Comparison of the percent of the state's coastal habitat that represented various water quality conditions for selected water quality parameters and for the integrated water quality index.

averages were > 4.0 mg/L. Approximately 2% of the state's tidal creek habitat had average DO levels < 3.0 mg/L and 13% of this habitat had DO levels between 3.0 and 4.0 mg/L, which is similar to the previous survey period (Van Dolah *et al.*, 2004a) Tidal creek sites often had a greater range in DO concentrations than the open water sites (data online).

Although numeric state DO standards apply to all waters, the SCECAP data continue to suggest that lower DO concentrations in tidal creeks may be normal during the summer months compared to larger water bodies. When making regulatory decisions in such situations, the practice of considering natural background conditions seems appropriate. Even so, creek sites with mean DO levels < 3.0 mg/L may not fully support biological assemblages, especially during periods when DO levels are less than 2.0 mg/L (hypoxic conditions). Hypoxic conditions are known to be limiting to many estuarine and marine biota (Gibson *et al*., 2000).

As noted in the previous two survey periods (Van Dolah *et al*., 2002a, 2004a), the instantaneous measures of bottom DO were, on average, lower than the mean DO values obtained from the 25-hr deployment of water quality datasondes among both the open water (0.7 mg/L difference) and tidal creek sites (1.1 mg/L difference, data online). In contrast to the previous surveys, these differences were statistically significant ($p < 0.002$) during the current survey. The instantaneous bottom DO measure at each site was only weakly correlated to the average bottom DO obtained from the 25-hr instrument deployment ($r^2 = 0.22$), which was also the case in the previous surveys. While instantaneous measures of DO and other water quality parameters are the only feasible approach for SCDHEC to use for the year-round assessment of coastal water quality, mean DO conditions are best measured over a longer period that includes both day and night measures during all tidal stages.

Finally, it should be noted that SCDHEC uses surface water quality measures for regulatory and reporting purposes. The mean differences between surface and bottom readings during the primary site visit was only 0.2 mg/L for both habitat types and only two open water sites had a difference in DO readings of more than 1.0 mg/L (data online). Thus, the surface readings should be reasonably protective of bottom water habitats for South Carolina waters.

pH

Measures of pH provide another indicator of water quality in estuarine habitats that has often been ignored by other sampling programs at the state or national level. Measures of pH are based on a logarithmic scale, so even small changes in the value can result in significant stress to estuarine organisms (Bamber, 1987, 1990; Ringwood and Keppler, 2002). Unusually low or high pH values may indicate the presence of pollutants (e.g. release of acids or caustic materials) or high concentrations of carbon dioxide (Gibson *et al.*, 2000). Because salinity and alkalinity affect the pH of estuarine waters, SCDHEC has established water quality standards that account for these effects. The pH in Class SA and SB tidal saltwater areas should not vary more than one-half of a pH unit above or below effluent-free waters in the same geologic area having a similar salinity, alkalinity and temperature, and values should never be lower than 6.5 or higher than 8.5. Shellfish Harvesting waters (SFH) shouldn't deviate more than 0.3 units from effluent-free waters. Based on these criteria, pH criteria were established for SCECAP assessments using data collected from pristine environments sampled in 1999-2000 (e.g. Cape Romain National Wildlife Refuge, ACE Basin and North Inlet-Winyah National Estuarine Research Reserves, SFH class saltwaters) to identify pH levels that were considered to represent good, fair, and poor conditions for polyhaline waters (> 18 ppt; Van Dolah *et al*., 2002a). For polyhaline waters, pH levels ≥ 7.4 are considered to be good. Values below 7.4 and above 7.1 pH units are considered to be fair since they represent the lower 10^{th} percentile of all pH records observed for polyhaline waters during the 1999-2000 survey. Values below 7.1 pH units are below the 0.5 pH unit variation allowed for effluent-free waters and are considered to be poor pH conditions. Criteria are still not established for lower salinity waters since the extreme drought conditions experienced from 1999-2002 limited the number of sites with salinities < 18 ppt. The return of normal rainfall conditions should allow us to develop criteria for oligohaline and mesohaline waters following the 2005-2006 survey now in progress.

The overall average pH observed in 2003-2004 based on the 25-hr measures was 7.3 in tidal creek habitats and 7.6 in polyhaline open water habitats, with approximately 79% of the state's polyhaline tidal creek habitat and 93% of the open water habitat having good pH conditions (Figure 3.2.2, data online). Criteria for lower salinity waters are still not available using the approach developed by SCECAP. As with the previous surveys, the mean instantaneous pH of surface waters within each habitat was within 0.1 pH unit of the mean bottom pH based on the continuous measurements. All mean values were also very similar to the averages observed in the 1999-2000 and 2001-2002 surveys (Van Dolah *et al*., 2002a, 2004a). Mean pH values were significantly lower in the tidal creek habitats compared to the open water habitats ($p < 0.001$) with a higher percentage of the state's polyhaline creek habitat having pH values considered to be only fair or poor compared to polyhaline open water habitat (Figure 3.2.2). Similar trends were noted in the previous two surveys (Van Dolah *et al*., 2002a, 2004a). Additionally, five tidal creek stations (RT032031, RT032046, RT032052, RT042062, RT042084) and two open water stations (RO036049, RO036054) had 25-hr pH means below the minimum (6.5) criteria established by SCDHEC. The locations of sites that had moderately low to very low pH values are provided in Appendix 2.

Nutrients

Nutrient concentrations in estuarine waters can become high due to runoff from upland urban and suburban developments, agricultural fields adjacent to estuarine habitats, riverine input of nutrient-rich waters from inland areas, and atmospheric deposition. High nutrient levels can lead to eutrophication of estuarine waters resulting in excessive algal blooms (including harmful algal species), decreased dissolved oxygen, and other undesirable effects that adversely affect estuarine biota (Bricker *et al*., 1999). Currently, there are no state standards in South Carolina estuarine waters for the various forms of nitrogen (except ammonia) and phosphorus. Therefore, the SCECAP data are compared to SCDHEC's historical database (SCDHEC, 1998a) to identify waters showing evidence of elevated nutrients. Values below the 75th percentile of the historical database are considered to be good, values above the 75th percentile and below the 90th percentile are considered to be moderately elevated (fair), and values above the 90th percentile are considered to be high (poor).

Nitrogen:

Total nitrogen (TN), as measured by the SCDHEC laboratory, is best represented by the sum of nitrate-nitrite and total Kjeldahl nitrogen (TKN). Based on historical SCDHEC (1998a) data, TN values ≤ 0.95 mg/L are considered to be good. Values > 0.95 mg/L and < 1.29 mg/L are considered to be fair since they are above the upper 75th percentile of the historical records and below the 90th percentile of those records. Values above 1.29 mg/L are considered to be poor since they represent the upper 90th percentile of the historical records.

In 2003-2004, the mean concentration of TN was 0.67 mg/L among the tidal creek sites and 0.66 mg/L among the open water sites. There was no significant difference between mean TN values observed in the tidal creek versus open water habitat ($p = 0.596$), which was also the case in the 2001-2002 survey, but not in the 1999-2000 survey when tidal creeks had a significantly higher nitrogen concentration compared to open water habitat. Approximately 93% of the nitrogen was in the form of TKN (organic fraction plus ammonia) when all stations were considered collectively. Mean nitrate-nitrite values in the creeks and open water sites were only 0.03 and 0.05 mg/L, respectively, which was similar to the values observed in the previous surveys.

Using the sum of the detectable values for nitrate-nitrite and TKN as an indication of TN enrichment, about 83% of open water habitat and 87% of tidal creek habitat had nitrogen levels indicative of good conditions. Fourteen percent of the state's open water habitat and 9% of the state's creek habitat had moderately elevated TN concentrations, considered to be fair (Figure 3.2.2, data online). Additionally, 3% of the open water habitat and 4% of the creek habitat had nutrient values considered to be poor. The percentage of the state's estuarine habitat with fair or poor TN concentrations was higher than observed in either the 1999-2000 or 2001-2002 surveys (Figure 3.2.3). This probably reflects the effects of increased runoff from upland habitat as compared to the drought period of the previous two surveys. Sites with very high TN concentrations were located in a creek in Clark Sound

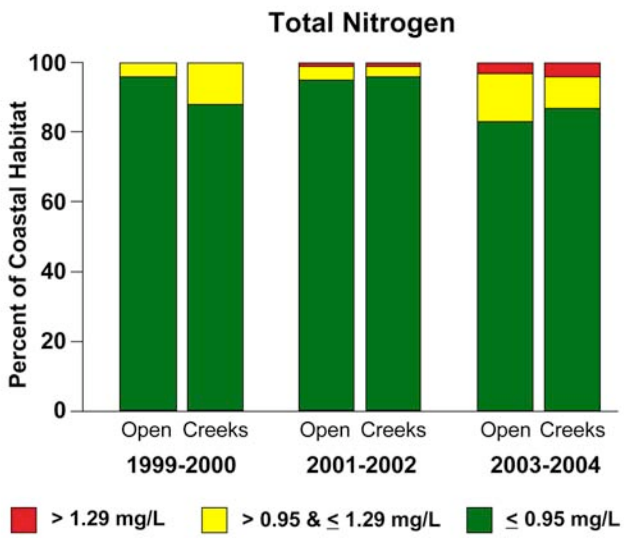


Figure 3.2.3. The percent of the state's coastal habitat representing various TN that are considered to be normal (green), fair (yellow), or poor (red) values relative to SCDHEC historical data during the three survey periods conducted to date.

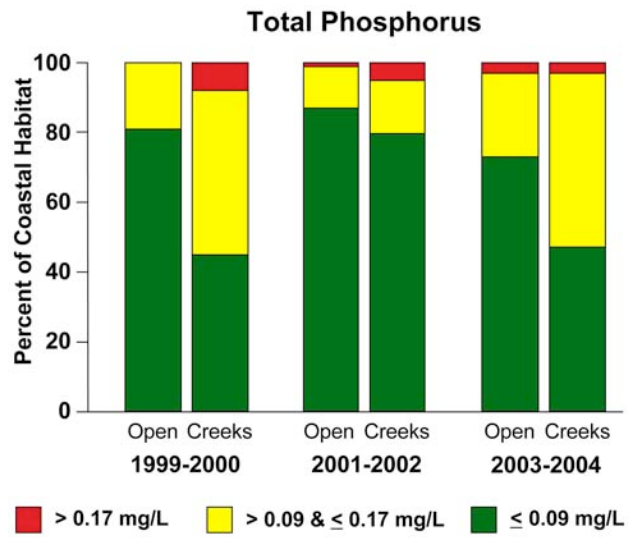


Figure 3.2.4. The percent of the state's coastal habitat representing various TP concentrations that are considered to be normal (green), fair (yellow), or poor (red) values relative to SCDHEC historical data during the three survey periods conducted to date.

off of Charleston Harbor (RT032050), the Intracoastal Waterway at Goat Island (RO036050), the Ashepoo River (RO036152), Winyah Bay at the mouth of the PeeDee River (RO046062), near Belle Isle Gardens (RO046064) and in the Ashley River (RT042192) near Middleton Gardens (Appendix 2). None of these sites had elevated concentrations of chlorophyll-*a*, another measure of possible estuarine eutrophication (see Chlorophyll-*a* section).

Phosphorus:

Based on SCDHEC historical survey data (SCDHEC, 1998a), total phosphorus (TP) levels ≤ 0.09 mg/L are considered to be good. TP concentrations > 0.09 and ≤ 0.17 mg/L represent concentrations above the 75th percentile and below the 90th percentile of historical records and are considered to be fair and. Concentrations > 0.17 mg/L are considered to be poor since they represent the upper 90th percentile of the historical observations. The mean TP measured by SCDHEC in 2003-2004 was 0.10 mg/L at the creek sites and 0.07 mg/L at the open water sites (data online). In contrast to the previous surveys in 2001-2002, this difference was statistically significant ($p = 0.002$) and comparable to the means observed during our first survey period in 1999-2000. Only 73% of open water habitat and 47% of tidal creek habitat had TP concentration considered to reflect good conditions. However, only 3% of the state's creek and open water habitat had TP concentrations that exceeded the 90th percentile (the threshold for poor conditions) of the SCDHEC historical database (SCDHEC, 1998a; Figure 3.2.2). The percentage of the state's coastal creek and open water habitat that was considered fair or poor with respect to TP concentrations was substantially greater than observed in 2001-2002, but not very different from the 1999-2000 survey (Figure 3.2.4). The relationships between changes in estuarine TP concentrations, regional rainfall patterns and

The upper Ashley River is home to several of South Carolina's historic plantation houses and managed gardens. Photo credit: Susan Tobias anthropogenic inputs remains unclear and deserves further attention.

Tidal creek sites with very high TP concentrations were located in the upper Ashley River near Runnymede Plantation and Middleton Gardens (RT032046, RT041294; Appendix 2). This latter creek also had very high total nitrogen concentrations. Open water sites with very high TP concentrations were near the mouth of the Pee Dee River and in Winyah Bay near Belle Isle Gardens (RO046062, RO046064; Appendix 2).

Chlorophyll-a

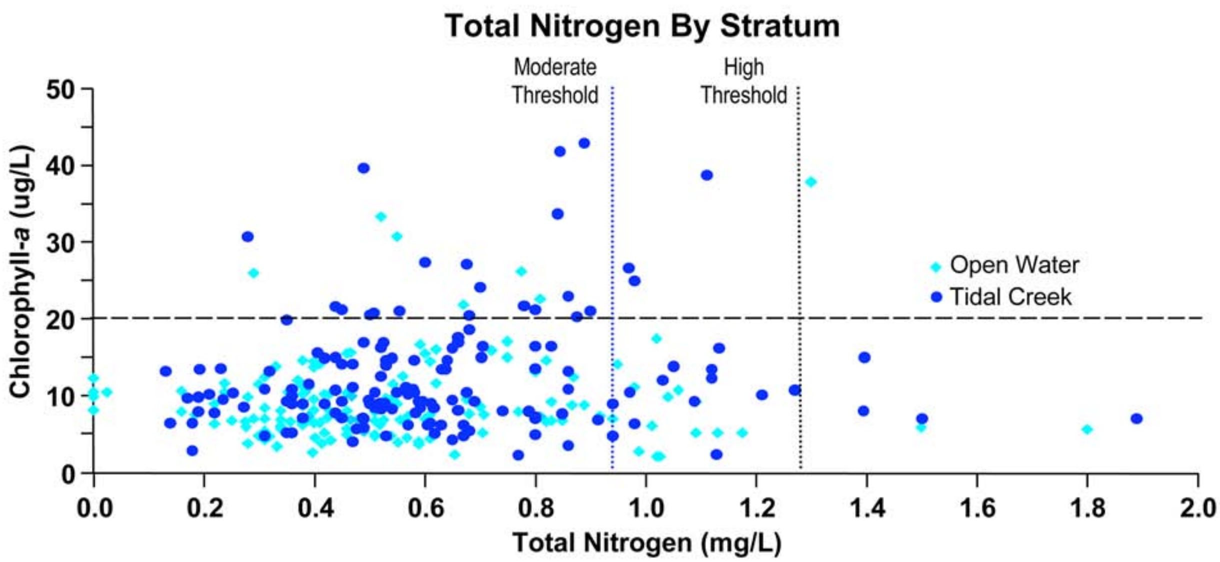
Our measure of phytoplankton biomass in the water column is based on chlorophyll-*a* concentrations. Other phytoplankton pigments were also examined using HPLC analyses to determine phytoplankton composition (see Section 3.4). High chlorophyll-*a* concentrations provide an indication of possible estuarine eutrophication since phytoplankton respond rapidly to enriched nutrient concentrations and can form blooms that result in poor water quality (e.g., low DO, large DO variations) and the presence of harmful algal species. For SCECAP, chlorophyll-*a* concentrations $\leq$ 12 µg/L are considered to be good. Chlorophyll-*a* values > 12 µg/L represent the upper 75th percentile of all chlorophyll-*a* concentrations measured by the SCECAP program and are considered to be only fair. Chlorophyll-*a* concentrations above 20 µg/L are considered to be high or poor based on criteria or guidelines published by Bricker *et al.* (1999) and the USEPA (2004).

The mean chlorophyll-*a* concentration was 11.8 µg/L in creek habitats and 7.6 µg/L at the open water sites. This difference was statistically significant ($p < 0.001$), but both means represent relatively low concentrations based on the SCECAP database (i.e., < 75th percentile). Using SCECAP criteria, 11% of the state's tidal creek and 1% of the open water habitat had chlorophyll-*a* concentrations considered to be poor (Figure 3.2.2). The slightly higher chlorophyll concentrations in tidal creeks may be reflective of the higher nutrient concentrations observed in the creeks. It may also reflect possible re-suspension of benthic algae from the creek bottoms and nearby marsh surfaces.

An analysis of the relationships between total nutrient concentrations and chlorophyll-*a* concentrations using all six years of available data showed very little correlation between TN and chlorophyll-*a* concentrations (r^2 =0.0185) or between TP and chlorophyll-*a* concentrations (r^2 = 0.0143) (Figure 3.2.5). This is similar to the findings obtained by Van Dolah *et al.* (2004a) in previous survey periods of estuarine habitats. Similarly, Brock (2005) could find no relationships between phosphorus and chlorophyll-a concentrations in brackish stormwater ponds in SC. Therefore, the poor relationships between TN and TP and chlorophyll-a suggest a need to reconsider the utility of using nutrient concentrations as indicators of eutrophication. The lack of a good correlation with either nutrient parameter is likely due to a combination of nutrient-algae dynamics and the high tidal amplitude present in South Carolina estuaries, the latter of which reduces formation of blooms that might otherwise occur in more stagnant waters or in estuaries that have much lower tidal flow.

Fecal Coliform Bacteria

Fecal coliform bacteria are sampled as a measure of potential health hazard in estuarine waters related to primary contact recreation such as swimming and shellfish harvesting. State fecal coliform standards to protect primary contact recreation requires a geometric mean count that does not exceed 200 colonies/100 mL based on five consecutive samples in a 30-day period and no more than 10% of the samples can exceed 400 colonies/100 mL. To protect for shellfish consumption, the geometric mean shall not exceed 14 colonies/100 mL and no more than 10% of the samples can exceed 43 colonies/100 mL (SCDHEC, 2004). Since only a single fecal coliform count is collected at each site during SCECAP surveys, compliance with the standards cannot be strictly determined, but the data can provide some indication of whether the water body is likely to meet standards. For SCECAP, we consider any sample with $\leq$ 43 colonies/100 mL to be good. Samples with > 43 colonies/100 mL and < 400 colonies/100 mL represent fair conditions (i.e., potentially not supporting shellfish harvesting) and any sample with > 400 colonies/100 mL represents poor conditions (i.e., potentially not supporting primary contact recreation).



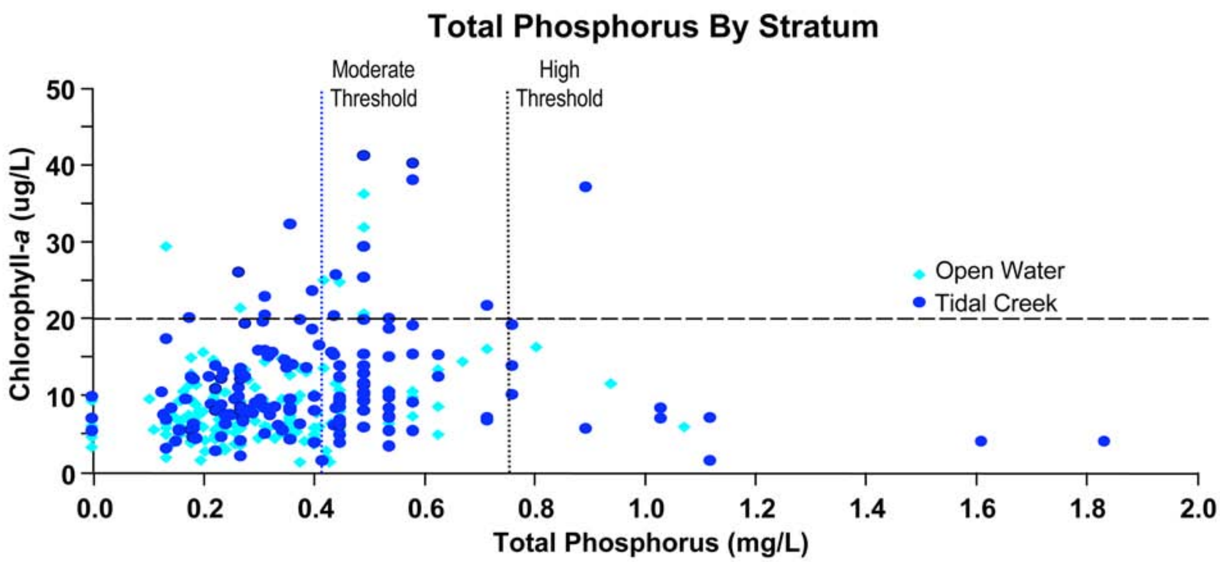


Figure 3.2.5. Summary of chlorophyll-a versus total nitrogen (TN) and total phosphorus (TP) measures collected at SCECAP sites sampled from 1999-2004. The vertical dotted lines represent the 75th and 90th percentile values based on a historical database (SCDHEC, 1998a). The horizontal dotted line represents the concentration of chlorophyll-a that is considered to be high by Bricker et al. (1999) and the USEPA (2004).

The arithmetic mean of fecal coliform measurements obtained during the 2003-2004 statewide assessments were 21.0 colonies/100 mL in open water and 80.2 colonies/100 mL in the creek sites (data online). This difference was statistically significant ($p < 0.05$) and more than double the mean fecal coliform concentrations observed in the 2001- 2002 survey (Van Dolah et al., 2004a). The relatively high mean for tidal creeks was largely due to the presence of very high fecal concentrations (range of 500-900 colonies/100 mL) at four tidal creek sites (R032046, RT032174, RT042062, and RT042194). Two of those sites were located in the upper Ashley River, which also had high nutrient concentrations. None of the open water stations had fecal coliform concentrations > 130 colonies/100 mL. Using the SCECAP criteria, approximately, 88% of the state's open water habitat also had good fecal coliform concentrations, 12% had moderately high fecal coliform concentrations and no sites had coliform colony counts > 400 colonies/mL (Figure 3.2.2). Approximately 78% of the state's creek

Box 3.2.2 Comparison of Sampling Protocols Used for SCECAP and Other SCDHEC Monitoring and Reporting Activities

A subset of sites sampled each year for SCECAP (Core Sites) is also sampled monthly by SCDHEC for a suite of water quality parameters used in Clean Water Act 305(b) reporting activities. This provides an opportunity to compare how the one-time SCECAP sampling approach compares with routine water quality sampling conducted by SCDHEC, using both the water quality criteria established for SCECAP and other water quality criteria used by SCDHEC for their 305(b) assessment.

12-Month Versus One-Time Assessments

Because the SCECAP Integrated Water Quality Score (IWQS) was developed based on a one-time visit at each site, it was necessary to devise a comparative approach for sample observations collected throughout the year at the same stations. To calculate a comparable IWQS for the monthly data, the general assessment approach used by SCDHEC for Clean Water Act reporting activities (SCDHEC, 2006) was adapted for application using SCECAP IWQS parameters and thresholds. This required scoring the monthly data obtained for the six water quality parameters as shown in Table A. The IWQS then was calculated following the single sample procedure (Van Dolah *et al*. 2004a).

Table A: Criteria used to code each parameter in order to translate SCDHEC 305(b) reporting methodology into the 12-month IWQS.

	SCDHEC 305(b) Parameter Codes As:		
Parameter	**Good**	**Fair**	**Poor**
Dissolved Oxygen pH Fecal Coliform	< 2 samples exceeded SCECAP fair threshold	≥ 2 samples exceeded SCECAP fair threshold	≥ 2 sample exceeded SCECAP fair threshold and ≥ 1 was poor
Total Nitrogen Total Phosphorus Chlorophyll-*a*	< 3 samples exceeded SCECAP fair threshold	≥ 3 samples exceeded SCECAP fair threshold	≥ 3 samples exceeded SCECAP fair threshold and ≥ 1 was poor

The one-time and 12-month assessments using the SCECAP IWQS thresholds produced very different conclusions (Figure A). Compared with the one-time assessment, the 12-month assessment indicates a considerably lower percentage of estuarine habitat is in good condition and a higher percentage is in fair or poor condition. Total phosphorus had the greatest influence on the differences in both the tidal creek and open water habitats, primarily based on the large number of individual sites classified as poor in the 12-month assessment as compared to the one-time assessment (Table B). In tidal creeks, chlorophyll-*a* and, to a lesser extent, fecal coliform bacteria also contributed to the overall difference in the classification of individual sites. Fecal coliform bacteria may also account for some of the differences in the open water habitat results.

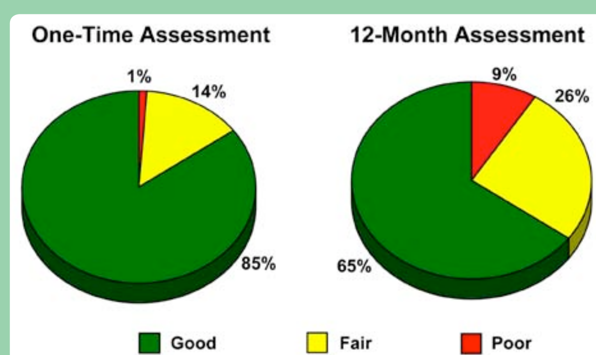


Figure A. Percent of the state's estuarine habitat that codes as good, fair, or poor based on the one-time SCECAP integrated water quality score and the 12-month integrated water quality score.

SCECAP IWQS Versus SCDHEC 305(b) Reporting

For a stricter comparison of the SCECAP IWQS and the SCDHEC 305b reporting, which includes additional parameters not used in the SCECAP IWQS, a different approach was required. Parameters considered in the 305(b) reporting include dissolved oxygen, pH, fecal coliform bacteria, turbidity,

Table B. Percent of open water and tidal creek core sites classified as good, fair, or poor based on 12-month and one-time assessments for each parameter.

		Open Water			Tidal Creek		
Measure	**Assessment**	**Poor**	**Fair**	**Good**	**Poor**	**Fair**	**Good**
IWQS	12-Month	6	23	71	23	37	40
	One-time	0	13	77	3	20	77
Dissolved Oxygen	12-Month	0	3	97	3	23	74
	One-time	3	6	91	0	20	80
pH	12-Month	17	8	75	18	5	77
	One-time	0	15	85	0	11	89
Fecal Coliform	12-Month	10	26	64	7	33	60
	One-time	0	19	81	7	23	70
Total Nitrogen	12-Month	3	10	87	13	0	87
	One-time	0	14	86	7	7	84
Total Phosphorous	12-Month	45	3	52	33	10	57
	One-time	7	16	77	3	50	47
Chlorphyll-*a*	12-Month	6	10	84	30	20	50
	One-time	0	6	94	13	17	70

ammonia, cadmium, chromium, copper, lead, mercury, nickel, and zinc, but the SCECAP IWQS only includes the first three parameters. The 305(b) report provides results on fecal coliform bacteria related to human health issues in a separate use category (recreational use) from the other parameters whose thresholds are set to protect aquatic organisms (aquatic life use). Therefore, the comparison of the SCECAP IWQS and the 305(b) report is limited to only two categories: *good* for both uses, or *other* (i.e., fair or poor for either or both uses). Additionally, the 305b report does not evaluate tidal creeks and open water habitats separately. Therefore, the two habitat types were combined for this comparison.

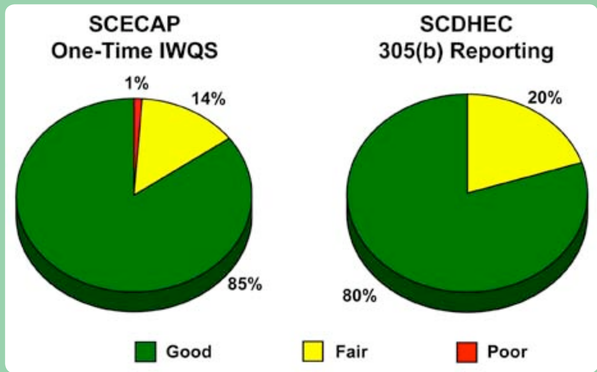


Figure B. Percent of the state's estuarine habitat that codes as good, fair, or poor based on the one-time SCECAP integrated water quality score and the SCDHEC 305(b) reporting methodology.

The SCDHEC 305(b) assessment results are in closer agreement with the one-time SCECAP data than the 12-month SCECAP IWQS despite using a very different set of parameters and employing different thresholds (Figure B). However, given the differences in assessment methods, parameters, and threshold values, this apparent degree of agreement may be coincidental.

In summary, it appears that the one-time assessment of state water quality condition used for SCECAP may not be as sensitive to detecting water quality impairment as a year-round sampling approach. It is important to note that state water quality criteria have not been established for nutrients and chlorophyll-a (3 of the 6 components of the SCECAP IWQS), so the differences may not be of great concern, especially considering that much of the difference is related to exceedances of the SCECAP criteria for phosphorus. Based on the lack of any significant relationship between phosphorus concentrations and chlorophyll-a concentrations, phosphorus may not be appropriate to include in future integrated water quality indices. SCDHEC and SCDNR staff will be reviewing both the SCECAP IWQS thresholds and list of parameters included on a periodic basis.

habitat was considered to have good fecal coliform concentrations, 16% was not likely to be suitable for shellfish harvesting and 6% had coliform concentrations considered to be very poor and not likely to be suitable for primary contact recreation or shellfish harvesting (Figure 3.2.2). The locations of sites that had moderately high to very high fecal coliform counts are provided in Appendix 2.

Even though the mean values of fecal coliform concentrations were much higher in both habitat types compared to the 2001-2002 survey, there was not a substantial change in the percentage of the state's habitat that had undesirable bacterial levels (Figure 3.2.6) The higher fecal coliform counts observed in creek habitats is most likely due to the proximity of these small drainage systems to upland runoff from both human and domestic wastes as well as wildlife sources, combined with the lower dilution capacity of creeks compared to larger water bodies. Greater protection of tidal creek habitats is warranted in areas where upland sources of waste can be identified and controlled.

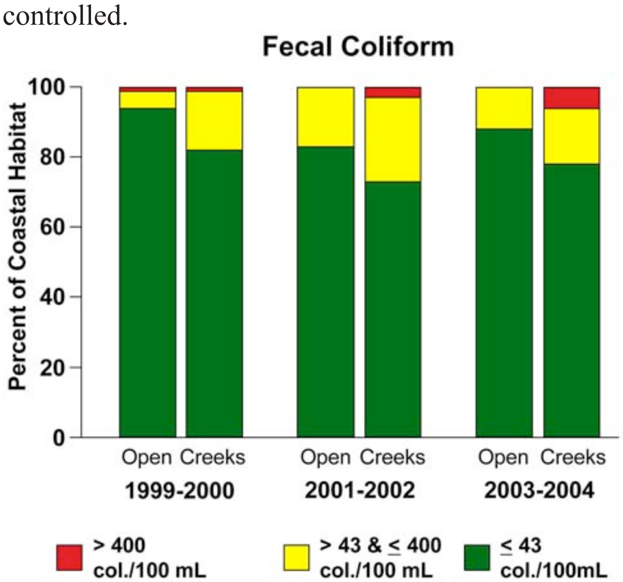


Figure 3.2.6. The percent of the state's coastal habitat representing various fecal coliform concentrations that are considered good (green), fair (yellow) and indicative of possible unsuitability for shellfish harvest, or poor (red) and indicative of possible unsuitability for primary contact recreation and shellfish harvesting during the three survey periods conducted to date.

Turbidity

Measures of water clarity provide an indication of the amount of suspended particulate matter in the water column. Exceptionally high turbidity levels may be harmful to marine life. South Carolina's estuarine waters are naturally turbid compared to many other states. SCDHEC has recently developed a maximum saltwater state standard for turbidity of 25 NTU. This corresponds to the 90th percentile of the SCDHEC saltwater database, which was obtained primarily from the larger estuarine water bodies. The 75th percentile of turbidity values obtained from SCECAP sampling was 15 NTU. Therefore for SCECAP, turbidity values $\leq$ 15 NTU are considered to be good, values > 15 NTU and $\leq$ 25 NTU are considered to be fair, and values > 25 NTU are considered to be poor because they contravene the SCDHEC standard.

While the SCECAP program recognizes the need to have turbidity standards, the standards are not incorporated into our overall water quality index at this time. Mean turbidities measured in the 2003-2004 survey by this program were 21.9 NTU in tidal creeks and 12.4 NTU in open water habitat (data online), which are very similar to the means noted in previous survey periods (Van Dolah *et al.,* 2002a, 2004a). As observed in the previous surveys, the difference between habitats was statistically significant ($p < 0.001$). Based on the single measure of turbidity taken at each station, approximately 29% of the tidal creek habitat exceeded the State standard, whereas only 7% of the open water habitat exceeded the standard (data online). Turbidity levels in tidal creeks may be naturally higher due to the shallow depths of these systems (i.e. surface samples are often within 1-2 m of the bottom) combined with re-suspension of the bottom sediments due to tidal currents. Because of the high turbidity levels observed in tidal creek habitats over the six years sampled by SCECAP (Box 3.2.1), this program has elected to not include this parameter in the integrated water quality index.

Integrated Assessment of Water Quality

SCECAP has developed an integrated measure of water quality using multiple parameters combined into a single index value (Van Dolah *et al*., 2004a). Six parameters are included in the index: dissolved oxygen (DO), pH, total nitrogen (TN), total phosphorus (TP), chlorophyll-*a* concentrations, and fecal coliform bacteria. DO and pH can indicate whether waters are stressful for many marine species. TN and TPs provide measures of nutrient concentrations, and combined with chlorophyll-*a* concentrations, these three parameters provide evidence of whether nutrient enrichment (eutrophication) may be occurring in South Carolina's estuaries. Fecal coliform concentrations provide an indication of the suitability of the water for shellfish harvesting and primary contact recreation.

Computation of the integrated water quality index is described by Van Dolah *et al*. (2004a; available online). For SCECAP, integrated scores > 4 represent good water quality conditions, scores > 3 but ≤ 4 represent fair water quality conditions, and scores ≤ 3 represent relatively poor water quality conditions, and scores .

Results of the 2003-2004 survey indicated that approximately 87% of the state's open water habitat had good water quality overall, 13% had fair quality, and none had poor water quality (Figure 3.2.2). In contrast, 75% of the state's creek habitat during this survey period had good, 22% had fair, and 3% had poor water quality. This was very similar to conditions observed in 2001-2002, which represented a drought period compared to the current survey. The creek sites with poor overall water quality were located in Rock Creek near the Ashepoo River and a tidal creek near Middleton Gardens in the Ashley River (Appendix 2).

As noted in the previous surveys (Van Dolah *et al.*, 2002a, 2004a), the higher percentage of fair and poor water quality conditions in creeks indicates that these habitats are often naturally more stressful

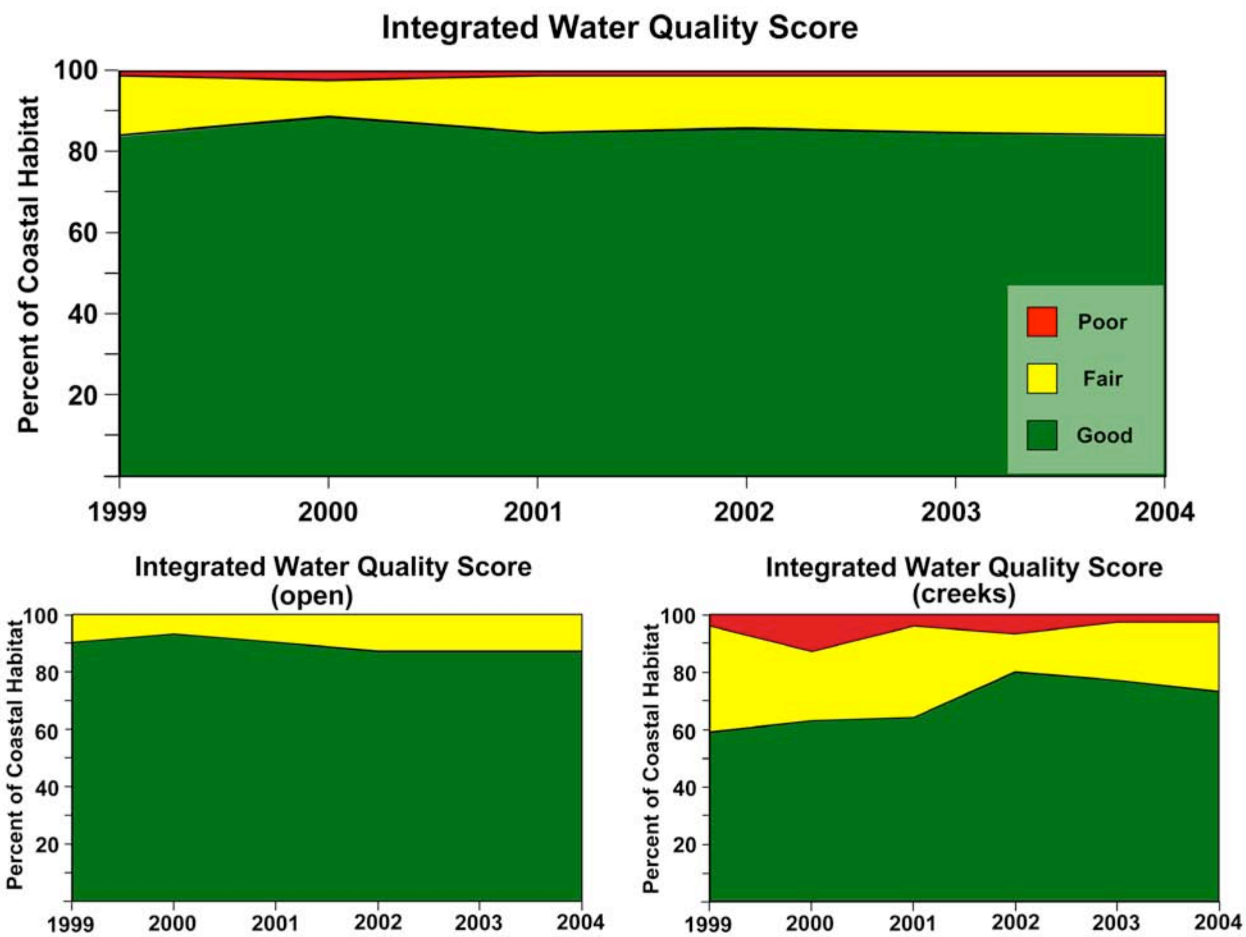


Figure 3.2.7. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated water quality score compared on an annual basis when tidal creek and open water habitats are combined and for tidal creek and open water habitats considered separately.

environments, especially since many of these sites were in relatively pristine locations. The higher percentage of creek habitat with fair or poor conditions may also reflect, in part, the relatively greater effect of anthropogenic runoff into these smaller water bodies due to their proximity to upland sources and their lower dilution capacity.

Comparison of the state's overall water quality condition on an annual basis indicated very little change over the six years sampled by SCECAP to date (Figure 3.2.7). This is surprising since the state's estuarine habitat was altered considerably by increased rainfall in 2003 and 2004 based on the changes in the proportion of the state represented by the various salinity zones (Figure 3.2.1). For all years, about 80% or more of the state's estuarine waters rank as good in quality using the SCECAP criteria, and generally less than 5% of the estuarine waters ranked as poor in quality. We anticipated that the increased rainfall experienced during 2003-2004 might have an impact on the state's overall estuarine water quality, but the resulting data did not confirm this. Although some of the component parameters did show evidence of considerable change, the actual concentrations observed among the various sites sampled in a given year, combined with the mitigating effects of those parameters that did not show much change, are the probable reasons for a lack in major changes in the integrated water quality index.

3.3 Sediment Quality

Sediment Composition

The composition of marine sediments can affect the structure of benthic communities, the exchange rates of gases and nutrients between the water column and seafloor, and the bioavailability of nutrients and contaminants to resident fauna (Gray, 1974; Graf, 1992). In general, muddier sediments (those with more silt and clay) tend to host a different set of species, reduce the movement of gasses and nutrients, and retain more contaminants than sandier sediments.

During the 2003-2004 monitoring period, sediments in open water habitats were on average 19.6% silt/clay while sediments in tidal creek habitats were 30.4% silt/clay, a difference that was significant ($p = 0.013$). Within each habitat type, the percent silt/clay was highly variable, with open water stations varying from 0.7-94.7% and tidal creek stations varying from 2.0-97.8%. The sediments at one open water station (2.0%) and four tidal creek stations (7.0%) had greater than 80% silt/clay (Figure 3.3.1). These values are similar to previous study periods (Van Dolah *et al.,* 2002a, 2004a).

Sediment Total Organic Carbon

Total organic carbon (TOC) represents a measure of the amount of organic material present in sediments. At very low TOC levels, little food is available for consumers resulting in a low biomass community; at very high TOC levels, enhanced sediment respiration rates lead to oxygen depletion and accumulation of potentially toxic reduced chemicals. Hyland *et al*. (2000) found that TOC levels below 0.5 mg/g (0.05%) and above 30 mg/g (3.0%) were related to decreased benthic abundance and biomass.

The TOC content of open water sediments averaged 0.8% while tidal creek habitats averaged 1.2%, a difference that was significant ($p = 0.048$). The TOC of open water habitats varied from 0.03% to 5.5% and that of tidal creeks varied from 0.05% to 5.5%. Based on the criteria in Hyland *et al.* (2000), the sediments were impaired with respect to TOC at 20% of open water habitats (14% too low, 6% too high) and 15% of tidal creek habitats (3% too low, 12% too high; Figure 3.3.1). These values are similar to previous surveys (Van Dolah *et al.,* 2002a, 2004a). The tendency of open water habitats to be characterized by lower TOC levels than tidal creek habitats likely reflects their greater distance from terrestrial sources of organic material.

Porewater Ammonia

Total ammonious nitrogen (TAN) provides a measure of the concentration of ammonia, a highly reduced and potentially toxic form of nitrogen, in marine sediments. Sources of ammonia include terrestrial runoff, atmospheric deposition and bacterial activity (nitrate reduction and ammonification), many of which are increasingly impacted by human activities, resulting in greater nitrogen loads in coastal environments (Driscoll *et al.,* 2003).

The median porewater ammonia concentration was 1.9 mg/L in open water habitats and 2.1 mg/L

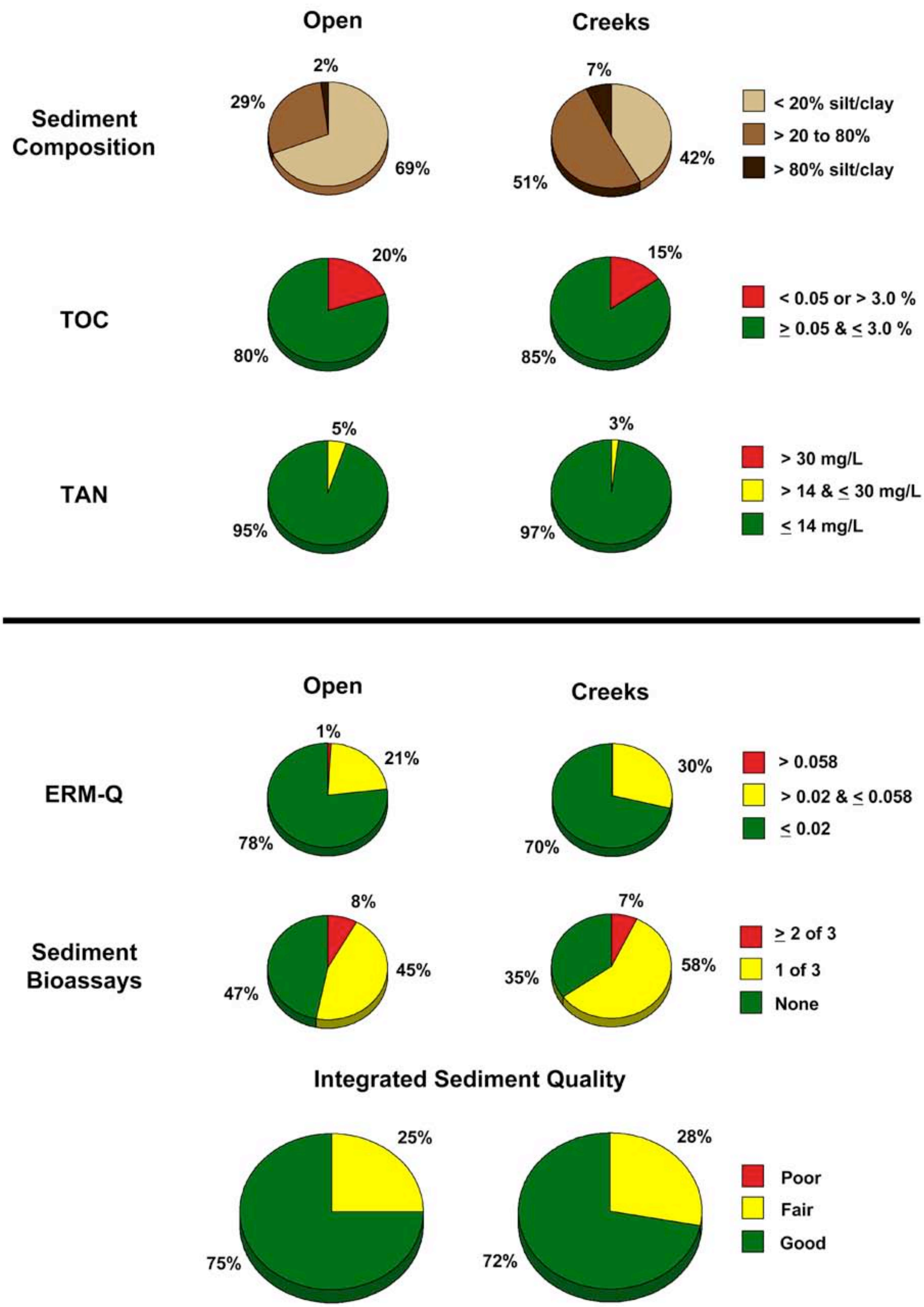


Figure 3.3.1. Comparison of the percent of the state's coastal habitat represented by various sediment quality conditions and integrated sediment quality scores.

in tidal creek habitats, a difference that was not significant. The TAN of open water habitats varied from 0.15 to 30.5 mg/L and that of tidal creeks varied from 0.1 to 25.3 mg/L. On average, less than half of one percent of South Carolina's open water or tidal creek habitat possessed ammonia concentrations characteristics of high stress habitats (Figure 3.3.1). A single station in open water had a TAN concentration of 30.5 mg/L but all remaining open water stations had TAN concentrations of less than 16 mg/L. The unusually high TAN concentration was found at station RO046076 near the confluence of Six Mile Creek and the Santee River. The area surrounding this station consists of extensive impoundments for waterfowl that may act as sources of nitrogen when water is released into the estuary during the late spring and summer.

The Santee River delta is highly impounded to attract waterfowl.

Contaminants

Contaminants enter coastal water bodies through direct release by users, runoff from terrestrial systems, and deposition from suspended material in the atmosphere. Common environmental contaminants include polycyclic aromatic hydrocarbons (PAHs; including compounds such as automobile oil), heavy metals (including mercury, chromium, etc), polychlorinated biphenyls (PCB's; including components of many flame retardants and electrical insulators manufactured before 1979) and pesticides (including DDT, etc.). Although SCECAP determined the levels of 160 contaminants in South Carolina's coastal waters, the consequences of many of these compounds to ecosystem function and human health remain uncertain.

Long and Morgan (1990) and Long *et al.* (1995, 1997) reviewed published toxicological studies involving 24 contaminants (all measured by SCECAP) and developed two metrics: Effects Range-Low (ER-L; concentration of a contaminant that resulted in adverse bioeffects in 10% of published studies) and Effects Range-Median (ER-M; concentration of a contaminant that resulted in adverse bioeffects in 50% of published studies). During the 2003-2004 monitoring period, 33 stations (including 12 open water and 21 tidal creek stations) had at least one contaminant that exceeded its published ER-L, and no station had a contaminant that exceeded its published ER-M. Four PAH's, the pesticide DDT, and 5 metals exceeded published ER-L (Table 3.3.1). The most widespread contaminant that exceeded its ER-L was arsenic. Arsenic accumulates in estuarine sediments as a result of the weathering of terrestrial rock, thus its presence in South Carolina's coastal sediments (particularly in tidal creeks) is likely a result of natural upland erosion. Disturbance of these sediments, such as may occur through slumping, erosion or dredging, however, can re-suspend buried arsenic (Saulnier and Mucci, 2000) making it available for uptake by estuarine fauna and increasing chances of contact with the human population.

To assess the overall bioeffect of the 24 contaminants with published guidelines, an Effects Range Median Quotient (ERM-Q) was calculated for each station. ERM-Q is calculated by dividing the measured concentration of each of the 24 contaminants by its ER-M values and then averaging the 24 values. Hyland *et al.* (1999) demonstrated that ERM-Q provides a reliable index of benthic stress in southeastern estuaries, with ERM-Q values ≤ 0.020 representing a low risk, values > 0.020 and ≤ 0.058 representing a moderate risk, and values > 0.058 representing a high risk of observing degraded benthic communities. The median ERM-Q of open water sediments was 0.010 and that of tidal creeks was 0.014, a difference that was not significant. ERM-Q varied from 0.001 to 0.076 in open water habitats and from 0.003 to 0.056 in tidal creek habitats. ERM-Q values were in the moderate risk range in 30% of the state's tidal creek habitat and 21% of the state's open water habitat and in the high risk range in 1% of the state's open water habitat (Figure 3.3.1). One open

Table 3.3.1. Contaminants that exceeded published ER-L. Also shown is the number of stations in each habitat type where this occurred.

Contaminant Type	Name	Number of Stations
PAH	Acenaphthene	2; RO036042, RO046071
	Anthracene	3; RO036042, RO036153, RT042067
	Fluorene	1; RO032032
	2-methylnapthalene	2; RO036044, RT042194
Pesticide	DDT	2; RO036044, RT042194
Metal	Arsenic	25; 8 open water, 17 tidal creek
	Cadmium	1; RO046073
	Copper	1; RO042070
	Lead	1; RT042193
	Nickel	7; RT032174, RT032188, RT046062, RT042070, RO046064, RO046076, RO046078

water station had an ERM-Q value within the high risk range: RO036042 in the Cooper River northeast of the mouth of Goose Creek (ERM-Q = 0.077). The Cooper River is extensively developed for industrial purposes, and the SCECAP station assessed here was situated near a U.S. Naval ammunition depot. This station was characterized by unusually high metal, PAH, PCB, and pesticide levels.

Coastal ERM-Q values have increased significantly since the start of SCECAP in 1999, particularly in open water habitats ($P = 0.018$; Table 3.3.2). Similarly, the percent of tidal creek and open water habitat in South Carolina having ERM-Q values indicative of moderate to high risk of contamination has increased consistently from 21% to 30% in tidal creek habitats and from 12% to 22% in open water habitats (Figure 3.3.2). A significant increase in metal concentrations ($P < 0.0005$) and increasing PAH contamination contributed most heavily to the increasing ERM-Q.

The Cooper River at Charleston is a busy shipping port and a heavily developed industrial area.

Table 3.3.2. Average ERM-Q values in open water and tidal creek habitats between 1999 and 2004. Averages were used rather than medians because only ERM-Q in developing and potentially polluted watersheds (a relatively small percent of SC coastal watersheds) would be expected to change over time, a response that would not be reflected by medians.

Habitat	1999	2000	2001	2002	2003	2004
Tidal Creek	0.0126	0.0131	0.0132	0.0171	0.0145	0.0152
Open Water	0.0148	0.0145	0.0175	0.0154	0.0180	0.0163

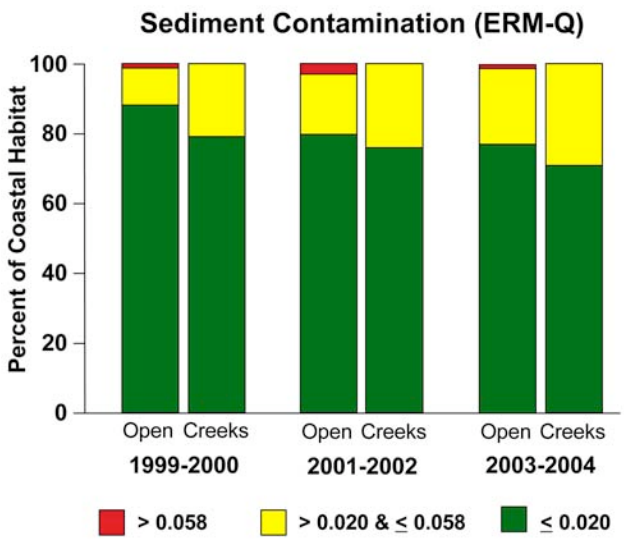


Figure 3.3.2. Change in ERM-Q in open water and tidal creek habitat since the start of SCECAP monitoring in 1999.

Toxicity Bioassays

Sediments may contain a wide range of contaminants, but the ability of those contaminants to negatively impact healthy biological communities depends on their availability to the resident fauna as well as interactive effects among the contaminants. Bioassays provide a means of determining the biological relevance of contaminant loads by examining the performance of living organisms in samples of native sediment (Ringwood and Keppler, 1998).

This SCECAP study applied three bioassays simultaneously—Microtox® bacterial growth, seed clam growth and amphipod survivorship—in order to provide a weight of evidence estimate of sediment toxicity to benthic fauna. Positive test results in at least two of the three assays indicates a high probability of toxic sediments, positive results in only one of the three assays indicates possible evidence of toxic sediments and no positive results indicates non-toxic sediments. Using these guidelines, 8% of the open water and 7% of the tidal creek habitat in South Carolina had a high probability of containing toxic sediments, and an additional 45% of open water and 58% of tidal creek habitat had evidence of possible toxicity (Figure 3.3.1).

Using the data available from all six years of SCECAP, we examined the ability of the bioassays to reflect ERM-Q scores. The number of assays showing positive results (excluding the amphipod assay) was significantly greater when ERM-Q scores were higher ($P < 0.0005$) indicating these assays provide a quantifiable estimation of sediment toxicity. While this describes a general tendency of the bioassays to detect toxicity at stations with higher contaminant loads, these bioassays did not entirely reflect contaminant levels. The amphipod assay produced only three positive results during the current study period, all at stations with good ERM-Q scores. This, combined with a general lack of amphipod toxicity in previous surveys, indicates that this assay does not perform well in this region. The Microtox® assay was very sensitive to stations with poor contaminant conditions (detected 100% of stations with high risk ERM-Q scores) but it displayed a tendency to generate many false positive results (detected toxic conditions at 41% of stations with good ERM-Q scores; Table 3.3.3). The clam assay was not as effective at detecting poor contaminant conditions (detected 43% of stations with high-risk ERM-Q

Table 3.3.3. Number of negative and positive Microtox® and seed clam bioassay results at stations with low, moderate and high risk ERM-Q scores. False positives are considered those assays with positive results at stations with a low-risk ERM-Q, and false negatives are considered those assays with negative results at stations with a high risk ERM-Q. By combining the Microtox and clam bioassays (combined columns), the ability to correctly detect low-risk (combined = 0), moderate-risk (combined = 1) and high-risk (combined = 2) improves.

	Microtox®		**Clam**		**Combined**		
ERM-Q	**-**	**+**	**-**	**+**	**0**	**1**	**2**
Low-risk	156	109	240	25	141	114	10
Moderate-risk	32	58	69	21	22	57	11
High-risk	0	7	4	3	0	4	3

scores), but it also did not generate a large number of false positive results (detected toxic conditions at 9% of stations with good ERM-Q scores; Table 3.3.3). Combining the Microtox® and clam bioassay to generate a score of 0 (positive in neither assay), 1 (positive in one assay), or 2 (positive in both assays) tends to decrease rates of false positive and false negative results. 53% of stations with good ERM-Q scored 0 in the combined assays, and 96% scored a 0 or 1. 43% of stations with poor ERM-Q scored as 2 in the combined assay and 100% scored as 1 or 2. Taken together, this supports coupling these bioassays in studies of sediment toxicity such that the Microtox® assay provides the ability to more consistently detect sites that have high sediment contaminant loads while the clam assay helps to limit the number of stations incorrectly identified as toxic by the Microtox® assay.

The "false positive" rate in the toxicity bioassays may reflect the effects of contaminants not incorporated into the ERM-Q or other environmental parameters. Most of the contaminants measured by SCECAP as well as many new unmeasured contaminants in the environment have no published bioeffects guidelines. For example, station RT042266 had unusually high concentrations of two PAH compounds considered to be carcinogenic, but these contaminants could not be incorporated into the ERM-Q due to lack of bioeffect guidelines. Environmental parameters other than sediment contaminants could also contribute to station toxicity. For example, while station RO046076 possessed an ERM-Q score indicative of fair conditions, both the Microtox® and clam bioassays indicated it was toxic; this station also possessed the lowest dissolved oxygen concentration of the current study period and the highest TAN value recorded in the six years of the SCECAP study.

Integrated Assessment of Sediment Quality

The integrated sediment quality index combines ERM-Q (a measure of total sediment contaminant levels) and sediment toxicity bioassays (a measure of the bioeffects of sediment contaminants). For SCECAP, an integrated sediment quality score of < 2 represents relatively poor sediment quality, scores ≥ 2 but < 4 represent fair sediment quality and scores ≥ 4 represent good sediment quality. During the 2003-2004 study period, 25% of open water and 28% of tidal creek habitat scored as fair while no habitat scored as poor (Figure 3.3.1). This suggests an improvement over the previous two study periods with the percent of habitat scored as good increasing from 72% to 75% in open water habitats and from 60% to 72% in tidal creek habitats (Figure 3.3.3). The large difference in the tidal creek habitats between study periods is due to an relatively small percentage (44%) of tidal creek stations receiving a good integrated sediment quality score in 2001. This same year had the highest proportion of false positive bioassay results (69%) in tidal creek habitats of any year. However, on a yearly basis, there has been no significant change in the integrated sediment quality scores of open water or tidal creek stations since the beginning of SCECAP monitoring (Fig 3.3.3).

The conflicting trends noted between the integrated sediment quality scores (which suggest improving or unchanging habitat quality) and ERM-Q (which suggest increasing contamination) likely reflect the averaging of ERM-Q and toxicity bioassay results in conjunction with a high rate of false positive and negative results among the bioassays. For example, the station with the highest ERM-Q during the current report period only scored as toxic in the Microtox® bioassay. Conversely, of the stations that scored as toxic in both the Microtox® and clam bioassays, 42% possessed low-risk ERM-Q values and only 13% possessed high-risk ERM-Q values. The result is that, once combined into an integrated score, these components average out to produce good or fair conditions at most stations. This stresses the importance of considering the individual components of the integrated scores (whether water quality, sediment quality or biological integrity) rather than relying solely upon the integrated scores for judging the state of our coastal waters.

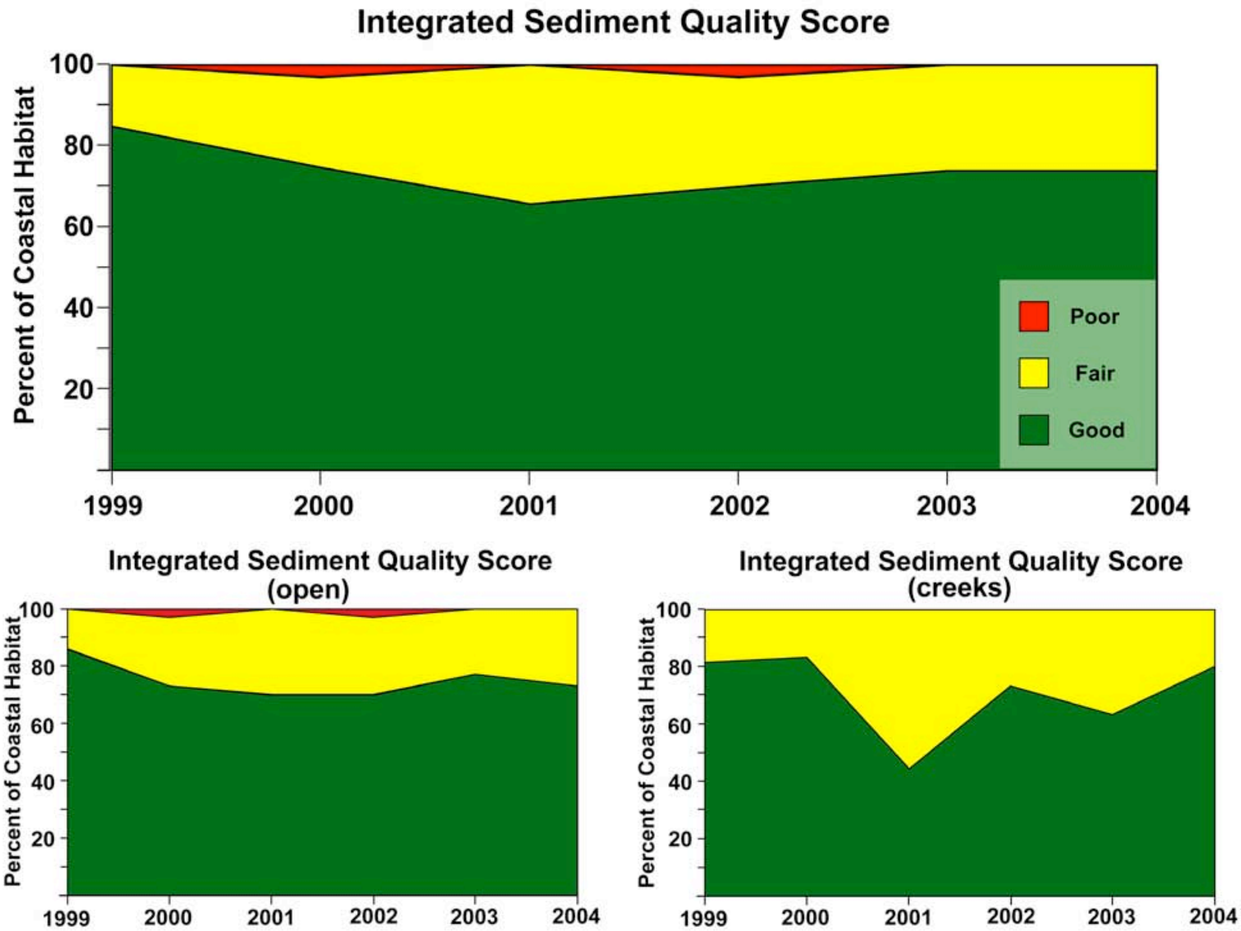


Figure 3.3.3. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated sediment quality score when tidal creek and open water habitats are combined and compared on an annual basis, and for tidal creek and open water habitats considered separately.

3.4 Biological Condition

Phytoplankton

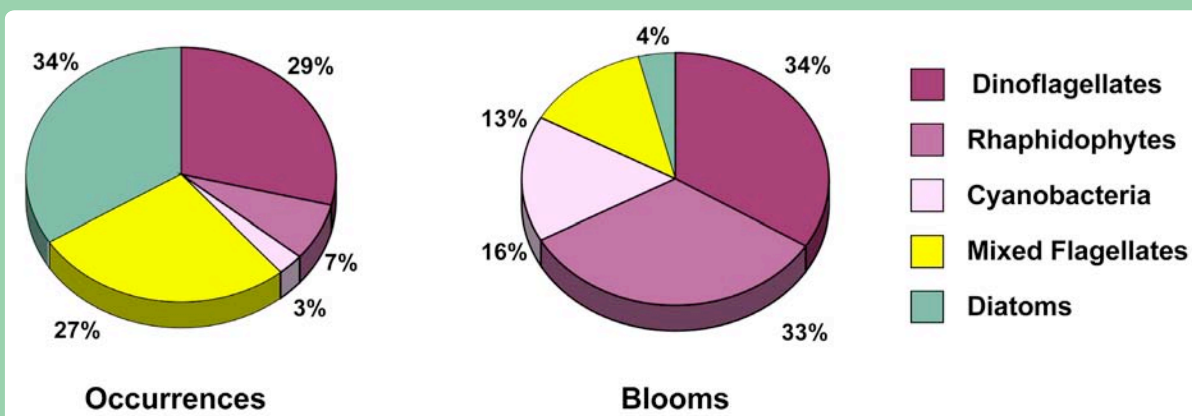
Phytoplankton biomass and composition serve as valuable indicators of estuarine health because these primary producers respond rapidly to increases in nutrient loading. Even short-term increases in nutrient inputs can promote blooms of algal species that are often present but not overabundant in balanced, healthy estuarine systems. Increased nutrient inputs promote a complex set of environmental responses, beginning with shifts in algal composition and leading to blooms of harmful species that have deleterious impacts on biota (Bricker *et al.,* 1999). Harmful species are defined by the potential to produce blooms or toxins that have negative effects on biological systems (causing fish kills for example) and in some cases cause human health problems (such as paralytic shellfish poisoning).

Most harmful algal species fall within the cyanobacteria, dinoflagellate and raphidophyte groups, although not all species within these taxa are harmful and some may appear within the diverse assemblages of pristine estuarine systems. These

Fishkill in a stormwater detention pond caused by a toxic cyanobacterial bloom. Photo credit: SCAEL

Box 3.4.1 Harmful Algae and Coastal Stormwater Ponds

In coastal stormwater ponds, the algal assemblage is dominated by harmful species that frequently produce blooms (> 1000 cell/ml). The algae producing these blooms are most frequently classified as dinoflagellates, raphidophytes, and cyanobacteria, which all have potentially toxic species. In the rapidly urbanizing South Carolina coastal zone, intensive landscape maintenance and turf management are significant sources of non-point source pollutant and nutrient loadings (Lewitus, *et al*., 2003). The stormwater best management practice of choice in this region is wet detention ponds. Typically, stormwater is piped directly into the ponds, but their capacity for processing pollutants is limited. These highly eutrophic ponds are "hot spots" for harmful algal blooms, many associated with measured toxins, fish kills, or shellfish health effects. Pond nutrient accumulations may also impact estuarine eutrophication through surface or groundwater transport (Pinckney *et al*., 2001). The pie charts below show the percent occurrence (by group) of all species and percent blooms (by group) of all blooms (>1000 cells/ml) between 2000 and 2005. During this period 325 blooms were recorded in brackish detention ponds and 25 in South Carolina's estuarine and coastal environment. Note that most of the blooms are attributed to dinoflagellates, raphidophytes and cyanobacteria.



The percent occurrence and percent of blooms of harmful species in eutrophic coastal locations (detention ponds and nearby impaired estuaries) from the larger South Carolina Harmful Algal Bloom database between 2000 and 2005.

taxa do, however, respond rapidly to increased nutrient levels and will dominate the biomass in enriched brackish environments (Ramus *et al.,* 2003). Unfortunately, there are far too many examples of these enriched brackish environments in South Carolina coastal zone. Stormwater ponds along the coast serve as incubators for harmful algal blooms and appear to be acting as a source of these harmful species into the adjacent estuaries (Box 3.4.1).

In contrast to this scenario of eutrophic water which reflects the anthropogenic effects of development, the majority of sites investigated in the 2003-2004 SCECAP program appeared to be in good condition and supported a diverse and desirable phytoplankton assemblage. The CHEMTAX evaluation of the percent biomass contribution by taxa demonstrated that 86-88% of the biomass was "healthy" (diatoms or mixed flagellates) and 13-14% was potentially harmful (dinoflagellates, raphidophytes or cyanobacteria). Diatoms are common in pristine estuaries and contribute efficiently to the food web (Lewitus *et al*., 1998). They contributed 48% of the biomass in the open water habitats and 41% of the biomass in the tidal creek habitats. Mixed flagellates were also dominant, and, while not as effective in transferring carbon and energy through the aquatic food web as the diatoms, they are considered desirable phytoplankton. The average relative biomass contributed by mixed flagellates was 39% in open water and 45% in tidal creek habitats (Figure 3.4.1). The smallest fraction of the biomass was contributed by the potentially harmful taxa including some dinoflagellates, raphidophytes and cyanobacteria. Only 13% of open water and 14% of the tidal creek site biomass was attributed to harmful taxa (Figure 3.4.1).

While the average percentage of harmful species at SCECAP sites is low for both tidal creek and open sites, there were some stations where the biomass of potentially harmful species exceeded 20% (Figure 3.4.2). Dinoflagellate percent biomass was elevated at six stations, while percent cyanobacterial biomass exceeded 20% at 12 stations. The station with the highest percent harmful cyanobacteria had a toxicity bioassay score indicative of a high probability of toxic sediments, and the station with the highest percent dinoflagellate relative biomass had an

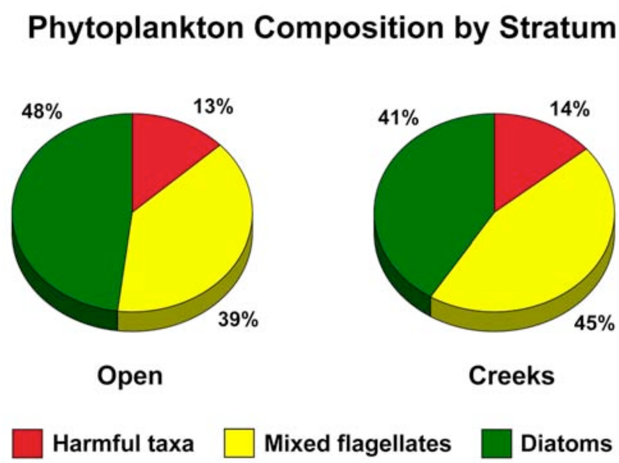


Figure 3.4.1. The percent contribution of diatoms, harmful taxa, and mixed flagellates to total phytoplankton community pigment biomass based on the mean of 2003-2004 samples from SCECAP open water and creek sites.

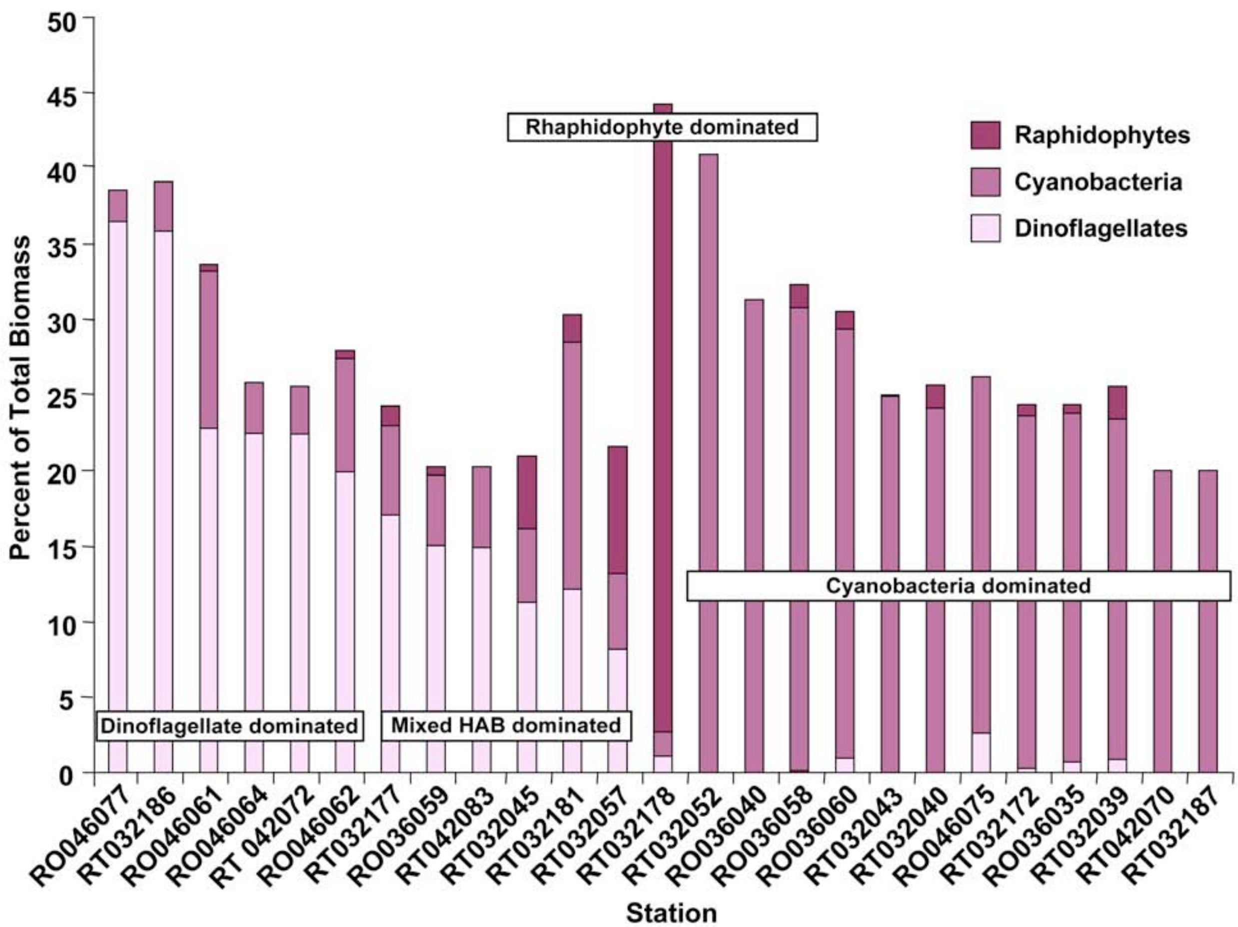


Figure 3.4.2. Percent biomass of harmful groups from stations with >20% of biomass attributed to potentially harmful taxon.

ERM-Q score indicative of high contaminant risk. Six stations had a mixed assemblage of harmful algal taxa and one station had primarily raphidophytes with *Heterosigma akashiwo* comprising 45% of the algal biomass (Figure 3.4.2). This station was within the Bulls Bay region where the South Carolina Algal Ecology Laboratory (SCAEL) documented a large (50 mi^2) offshore bloom of *Heterosigma akashiwo* in April 2003 (Keppler *et al.,* 2005).

The effects of the prolonged drought from 1999-2002 and a return to higher rainfall during 2003 were apparent in a decrease in salinity and relatively high nutrients levels during 2003 (see Section 3.2). Species that are generally confined to salinities of < 5 ppt include the cyanobacteria, euglenoids, and chlorophytes. These three groups were not present in the samples collected during 2001-2002, but did appear in the 2003 assemblages at seven tidal creek sites and nine open water sites (Figure 3.4.3). The salinity of the sites containing the euglena species varied from 0.1- 17.9 ppt, while the average salinity at sites with cyanobacterial species present was 13.9 ppt for creeks and 14.1 ppt for open water sites.

Another group which increased in diversity during 2003-2004 was the raphidophytes. These potentially ichthyotoxic (fish-killing) species tend to occur in brackish water ranging from 10-25 ppt, and can bloom rapidly in response to nutrient-rich freshwater inflows (Honjo, 1993). The salinity ranges of the raphidophyte species noted in the 2003-2004 SCECAP samples was from 12 - 29 ppt (Figure 3.4.3).

While the overall biomass of the phytoplankton is attributed to desirable species, there were harmful species present during the 2003-2004 sampling period. Table 3.4.1 lists the number of occurrences in the SCECAP phytoplankton database of the potentially harmful species. The cyanobacterial species noted are all potential bloom formers and most can produce toxins (hepatotoxins and neurotoxins). Only one diatom species of concern was documented, but this species (*Pseudo-nitzschia* cf *delicatissima*) can produce domoic acid, a potent neurotoxin (Horner *et al*., 1997). Many of the dinoflagellates listed are capable of producing blooms and have been associated with fish kills in South Carolina and around the world. A few of the known toxin producers documented by SCECAP included *Alexandrium*, *Gambierdiscus* and *Prorocentrum.* The final group noted are the raphidophytes that frequently have been associated with fishkills in South Carolina stormwater

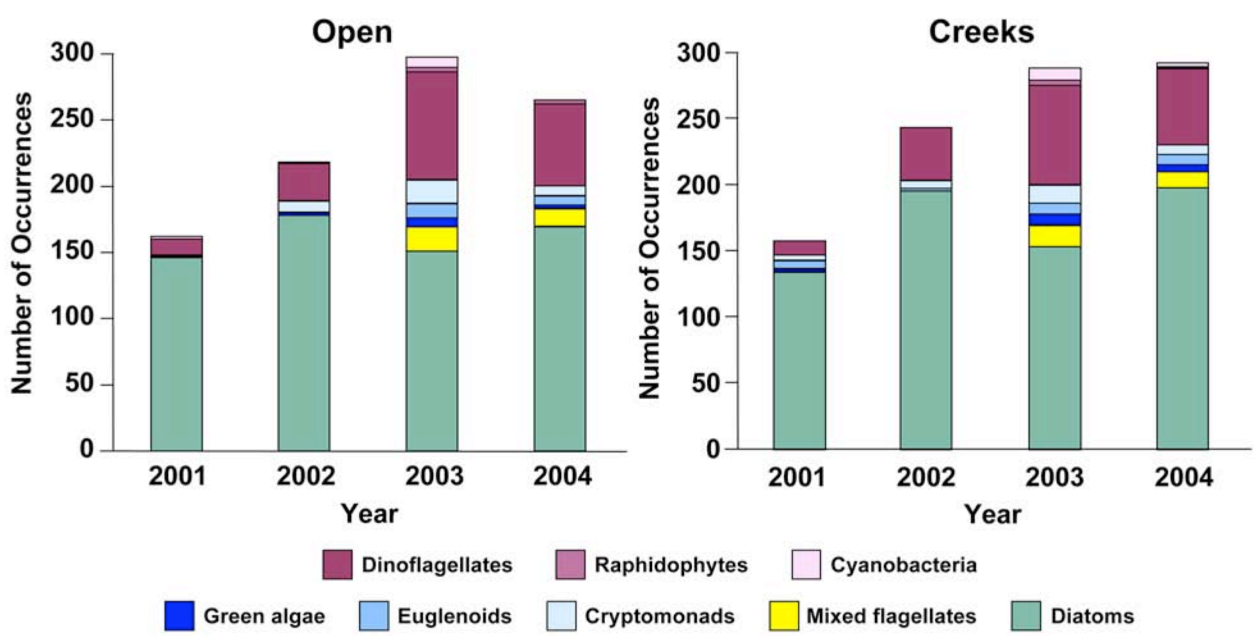


Figure 3.4.3. Occurrence of dominant taxonomic groups in open water and tidal creek sites. The number of taxa increased during the current study period coincident with a decrease in salinity, and the additional groups (green algae, euglenoids, and cyanobacteria) tend to occur in lower salinity water.

Table 3.4.1 Number of open water and tidal creek stations where potentially harmful phytoplankton species were identified. Included are whether each species is toxin-forming (toxic) or bloomforming (blooms) as well as the toxins and/or ecological effects produced.

Phytoplankton Species	Open Water	Tidal Creek	HAB Category	Known Toxins, Effects
Cyanobacteria				
Anabaena sp.		1	toxic	Anatoxins, Saxitoxins, Microcystins, LPS
Aphanizomenon sp.		1	toxic	Saxitoxins, Cylindrospermopsins, LPS
Microcystis aeruginosa		1	toxic	Microcystins, LPS
Microcystis incerta		1	blooms	
Oscillatoria sp.	6	6	toxic	Anatoxin, LPS
Planktothrix sp.		1	toxic	Anatoxin, LPS
Pseudanabaena sp.	1	1	toxic	unknown neurotoxin
Spirulina sp.	1		blooms	
Diatoms				
Pseudo-nitzschia cf delicatissima	1	1	toxic	Domoic acid
Pseudo-nitzschia sp.	9	8	some toxic	Domoic acid
Dinoflagellates				
Akashiwo sanguinea	14	20	blooms	
Alexandrium sp.	1		toxic	Hemolysin, PSP-causing compounds
Amphidinium sp.	5	2	toxic	Hemolysins
Gambierdiscus sp.	1		some toxic	Ciguatoxin- and Maitotoxin-like compounds
Gyrodinium pingue	4	7	blooms	associated with fishkills in SC
Gyrodinium instriatum	1	1	blooms	associated with fishkills in SC
Heterocapsa rotundata	28	20	blooms	associated with fishkills in SC
Heterocapsa triquetra	1		blooms	associated with fishkills in SC
Karlodinium micrum	16	8	toxic	karlotoxin, ichthyotoxic
Krypto-imposter	4	12	blooms	associated with shellfish stress in SC
Kryptoperidinium foliaceum	4	21	blooms	associated with shellfish stress in SC
Pfiesteria-like organism	2	5	toxic	associated with fishkills in SC
Prorocentrum c.f. lima		1	toxic	Okadaic acid, Dinophysis toxins 1 & 2
Prorocentrum micans	1		blooms	associated with fishkills in SC
Prorocentrum minimum	4	3	toxic	Unknown toxins
Prorocentrum sp.		1	some toxic	Okadaic acid, Dinophysis toxins 1 & 2
Raphidophytes				
Chattonella subsalsa	2		blooms	associated with fishkills in SC
Chattonella verruculosa		1	toxic	icthyotoxic
Fibrocapsa japonica	1		toxic	icthyotoxic
Heterosigma akashiwo	2	2	toxic	icthyotoxic
Heterosigma sp.	1	2	toxic	icthyotoxic

ponds. The raphidophytes *Heterosigma akashiwo, Fibrocapsa japonica*, and *Chattonella subsalsa*, also found by SCECAP in South Carolina's coastal waters, have been implicated in numerous fish kills globally (Honjo, 1993).

While none of these species were present in high abundance and no toxins were detected in the samples collected for the SCECAP study, they are present and potentially capable of responding rapidly to future anthropogenic nutrient enrichment. It is imperative that the development of our coastline be tempered by thorough urban planning and effective watershed management in order to prevent harmful algal blooms and ensure the health of our estuaries.

Benthic Communities

Benthic macrofauna serve as ecologically important components of the food web by consuming smaller organisms living in or on the sediments, detritus, or planktonic food sources and in turn serving as prey for finfish, shrimp, and crabs. Benthic macrofauna are also relatively sedentary, and many species are sensitive to varying environmental conditions. As a result, benthic organisms are important biological indicators of water and sediment quality and are useful in monitoring programs to assess overall coastal and estuarine health (Hyland *et al*., 1999; Van Dolah *et al*., 1999).

Mean density of benthic organisms across all stations sampled during the 2003-2004 study period varied from 63 to 37,113 individuals/m^2 (mean= 3,628 individuals/m^2). The mean density of organisms collected in open water habitats (4,182 individuals/m^2) was greater than the density in tidal creek habitats (3,076 individuals/m^2), although the difference was not statistically significant ($p = 0.952$, Figure 3.4.4). The density of benthic organisms in open water habitats has been consistently higher than in tidal creek habitats in all three surveys conducted by SCECAP to date (Van Dolah *et al*., 2002a; 2004a). The mean density of organisms collected during the 2003-2004 study period was 25% lower than the mean density collected in the 1999-2000 study period (average = 4,722 individuals/m^2) and 30% lower than those collected in 2001-2002 (average = 5,208 individuals/m^2). The first two study periods (1999-2002) occurred during a drought period in South Carolina (South Carolina State Climatology Office), while the current study period began after the drought was lifted in April, 2003. The differences in benthic faunal density may reflect changes in salinity between the previous study periods when drought conditions persisted (Van Dolah *et al*., 2002a; 2004a) and the current study period when more normal rainfall patterns returned (see section 3.2 and Box 3.4.2).

The overall number of species (species richness: S) varied from two to 64 taxa per grab (average = 17), and species diversity (H') varied from 0.40 to 4.49 (average = 2.62). The mean number of species

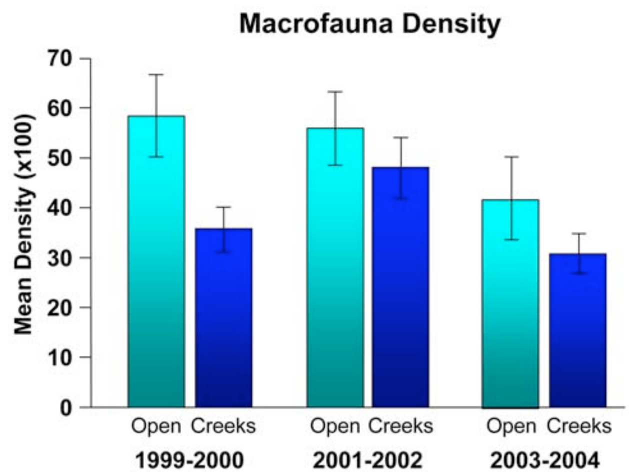


Figure 3.4.4. Mean density (number per m^2) of benthic fauna collected in open water and tidal creek habitats during the three study periods.

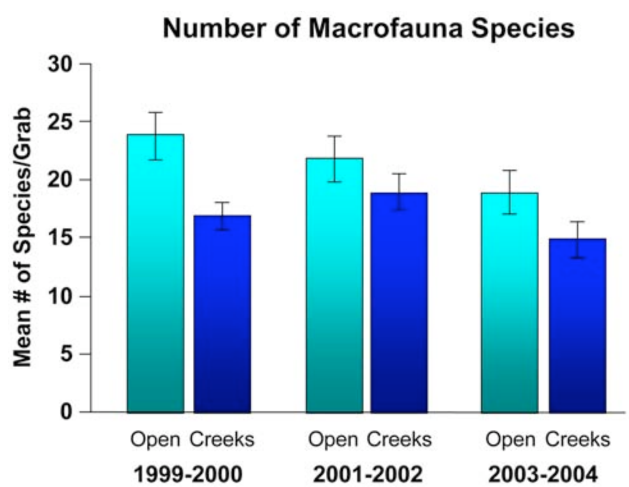
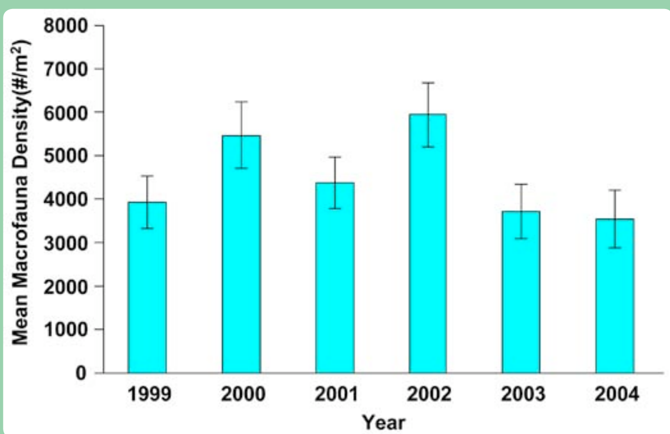


Figure 3.4.5. Mean number of species of benthic fauna collected in open water and tidal creek habitats during the three study periods.

Box 3.4.2 Rainfall, Salinity and Benthic Invertebrates

How does salinity affect estuarine benthic communities?

Salinity in an estuary varies with daily tides, season, volume of fresh water inflow, and proximity to the open ocean. Estuarine salinities are usually highest at the mouth of a river where ocean water enters, and lowest upstream where freshwater inflow is greatest. However, drought conditions can significantly alter the water quality of an estuary, particularly by allowing high salinity water to penetrate further upstream. Salinity is the major natural environmental factor controlling the distribution of benthic organisms in estuaries (Attrill & Power, 2000; Magnien *et al*., 1987). While benthic estuarine fauna are adapted to handling a fairly broad range of salinities, unusually high or low salinities and large changes in salinity can negatively affect their survival, growth and reproduction. During the current SCECAP study period, average salinity decreased and salinity ranges increased in both tidal creek and open water habitats as compared to previous study periods. Concurrent with this change was a 30% decrease in the mean number of organisms per m^2 collected by SCECAP sampling in South Carolina's sediments. Additionally, seven stations sampled in the current study period had salinity ranges greater than 20 ppt throughout a 25-hour monitoring period. Six of those stations also had low densities of benthic organisms (<1000/m^2), suggesting evidence of biological stress. This trend may reflect salinity effects directly, but it also may reflect other factors associated with increased terrestrial runoff, such as increased contaminant loads.



Abundance of benthic organisms (mean number per m^2) collected each year since the start of SCECAP monitoring in 1999.

and overall species diversity per grab were higher in open water habitats (S = 18.8, H' = 2.75) than in tidal creek habitats (S = 15.2, H' = 2.49) during the current study period (Figure 3.4.5). Although not significant, the trend of higher values at open water stations was also observed in the two previous study periods. No significant differences were observed in the average number of species or diversity estimates per grab among the three survey periods conducted to date, when all stations were considered collectively or when both habitat types were compared separately.

In order to compare the general taxonomic composition of organisms collected during each study period, all benthic species were classified into one of four groups: polychaetes, amphipods, mollusks, or other taxa (primarily oligochaetes, nemerteans, isopods, and decapods). The mean abundances of amphipods and mollusks were significantly greater in open water than in tidal creek habitats ($p = 0.013$; $p=0.032$, respectively). Polychaetes and other taxa were found in greater abundances in tidal creek habitats than in open water habitats, but these differences were not significant ($p > 0.05$). The percent abundance of polychaetes observed in both habitat types during 2003-2004 was very similar to that observed in the 1999-2000 survey, but about 10% lower than observed during the 2001-2002 survey period (Figure 3.4.6). Slightly higher percentages of amphipods and lower percentages of other taxa were found during the current sampling period at open water habitats when compared to the two previous study periods, while the opposite trend was observed at tidal creek habitats (Van Dolah *et al*., 2002a; 2004a). Minimal

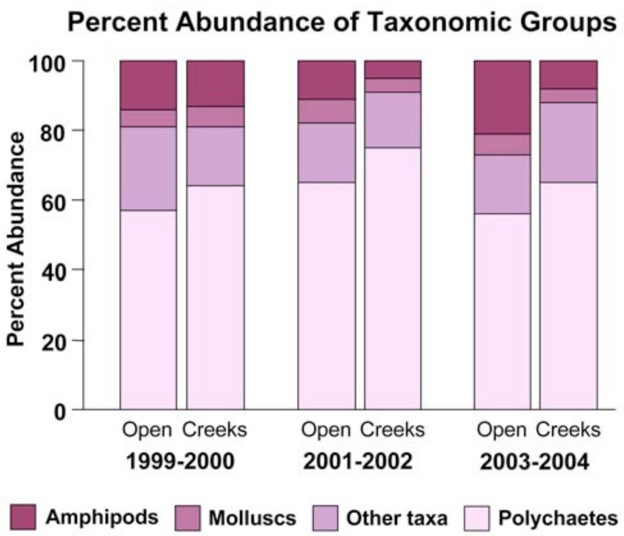


Figure 3.4.6. Percent abundance of organisms representing general taxonomic groups collected in benthic grabs at open water and tidal creek sites during the three study periods.

changes in mollusk abundances were observed across all study periods.

The number of species in each taxonomic category varied by habitat type. Open water stations collectively included 144 polychaete species, 48 amphipod species, 56 mollusk species, and 77 other taxa. Tidal creek stations collectively included 119 polychaete species, 38 amphipod species, 47 mollusk species, and 64 other taxa. There were significantly more amphipod species found at open water stations than at tidal creek stations sampled during the current study ($p = 0.009$). The number of species representing the other taxonomic groups (polychaetes, mollusks, and other taxa) were not significantly different between the habitat types. There were few significant differences between study years with respect to the number of species representing various taxonomic categories in either open water or tidal creek stations. One exception was a significantly greater number of polychaete species in tidal creek habitats during the 2001-2002 study period than during the 2003-2004 study period ($p = 0.037$).

The five dominant taxa collected during the 2003-2004 study period comprised 29% of the overall abundance across all stations (Table 3.4.2). These taxa included the polychaetes *Streblospio benedicti*, *Scoletoma tenuis*, *Mediomastus* sp. and *Tharyx acutus*, and the amphipod *Ampelisca abdita*. Of the five most abundant taxa, only *A. abdita* occurred at less than 50 percent of the stations sampled (Table 3.4.2). Nemertean worms (the 24th most abundant taxon) occurred at the largest percentage of stations (65%). Two of the five dominant taxa collected in 2003-2004, *S. benedicti* and *S. tenuis*, were also among the five dominant taxa collected in the 1999-2000 and 2001-2002 study seasons (Van Dolah *et al*., 2002a; 2004a).

In open water habitats, the five most abundant taxa also comprised 29% of the total abundance and included the polychaetes *S. tenuis*, *S. benedicti*, *Sabellaria vulgaris* and *Exogene* sp. and the amphipod *A. abdita*. The polychaete *Caulleriella* sp. was among the top five organisms collected in open water habitats in the previous two study periods, but was substantially less abundant during 2003-2004 (Table 3.4.2). The five most abundant taxa in tidal creek habitats together comprised over 38% of the total abundance of benthic tidal creek fauna and included *S. benedicti*, *S. tenuis*, *T. acutus*, *Mediomastus* sp. and the oligochaete *Tubificoides wasselli*. *Streblospio benedicti*, *T. wasselli*, and *S. tenuis* have been among the top five taxa collected in tidal creek habitats during all three study periods.

Streblospio benedicti, the numerically dominant species overall and in tidal creek habitats, was found in significantly greater abundances in tidal creek habitats than in open water habitats ($p = 0.004$). The same trend was observed in the 1999-2000 study period, but *S. benedicti* was found in significantly greater abundances in open water habitats during the 2001-2002 study period (Van Dolah *et al*., 2002a; 2004a). *Streblospio benedicti* is generally sensitive to changes in salinity, and its abundance tends to decrease at lower salinities (Reish, 1979). Over the three study periods, the average salinity in tidal creek habitats has consistently decreased (see section 3.2), and *S. benedicti* abundances have as well. The second most abundant organism in tidal creek habitats was the oligochaete *T. wasselli*, but it was not particularly abundant in open water habitats. During previous study periods, *T. wasselli* was among the top ten numerically dominant organisms in both open water and tidal creek habitats. However, *T. wasselli* prefers a mesopolyhaline (5-30 ppt) environment. The amount of coastal estuarine habitat in this salinity

Table 3.4.2. Densities and percent occurrences of the 50 numerically dominant benthic organisms collected in 2003 and 2004, which represent 82% of the overall abundance. A = amphipod, M = mollusk, P = polychaete, O = other taxa.

				Open Water		Tidal Creek	
Species Name		Mean Total Abundance at All Stations (#/grab)	% of Stations Where Present	Mean Abundance by Station (#/grab)	% of Stations Where Present	Mean Abundance by Station (#/grab)	% of Stations Where Present
Streblospio benedicti	P	1640	63	7	52	20	75
Scoletoma tenuis	P	947	52	9	43	7	60
Ampelisca abdita	A	925	38	13	33	2	42
Mediomastus sp.	P	686	57	7	57	4	57
Tharyx acutus	P	673	50	6	48	5	52
Sabellaria vulgaris	P	666	22	10	28	1	15
Tubificoides wasselli	O	657	34	2	32	9	37
Exogone sp.	P	553	29	7	35	2	23
Tubificoides brownae	O	412	46	4	43	3	48
Actiniaria	O	412	21	3	23	4	18
Scoloplos rubra	P	305	44	2	35	4	53
Paraprionospio pinnata	P	296	36	3	38	2	33
Polydora cornuta	P	273	28	1	23	4	33
Parapionosyllis sp.	P	262	12	3	17	1	7
Nereis succinea	P	233	43	1	37	2	48
Tubificidae sp. b	O	222	30	2	32	1	28
Caulleriella sp.	P	212	13	0	15	3	12
Spiochaetopterus costarum oculatus	P	200	32	2	32	2	32
Ampelisca verrilli	A	197	16	2	20	1	12
Melita nitida	A	196	23	1	20	2	25
Heteromastus filiformis	P	195	43	0	27	3	58
Scolecolepides viridis	P	191	10	2	8	2	12
Nemertea	O	183	65	1	68	2	62
Aphelochaeta sp.	P	180	26	1	22	2	30
Tubificidae	O	177	25	1	18	2	32
Polydora socialis	P	168	27	1	32	2	22
Carinomella lactea	O	160	33	2	35	1	32
Batea catharinensis	A	151	22	2	28	0	15
Cyathura burbancki	O	142	21	2	27	1	15
Paracaprella tenuis	A	135	17	2	22	1	12
Mediomastus californiensis	P	134	14	2	15	0	13
Protohaustorius deichmannae	A	132	8	2	13	0	2
Tellina agilis	M	131	27	2	32	1	22
Aricidea wassi	P	126	13	2	25	0	2
Polycirrus sp.	P	125	7	2	7	1	7
Tubificoides heterochaetus	O	119	12	1	10	1	13
Aricidea bryani	P	119	24	1	23	1	25
Mediomastus ambiseta	P	117	23	1	28	1	18
Acanthohaustorius millsi	A	114	6	2	8	0	3
Monticellina sp.	P	112	19	1	22	1	17
Leptonacea sp.	M	111	16	2	23	0	8
Phoronida	O	109	16	1	15	1	17
Cirrophorus sp.	P	103	25	1	30	1	20
Unciola serrata	A	101	5	2	10	0	0
Sphenia antillensis	M	97	23	1	25	0	22
Cirratulidae	P	96	31	1	30	1	32
Streptosyllis sp.	P	86	21	1	25	0	17
Leitoscoloplos fragilis	P	81	34	1	38	1	30
Glycera americana	P	78	44	1	45	1	43
Pelecypoda	M	73	33	1	40	0	25

range was approximately 8% lower (see section 3.2) than we observed in the the 2001-2002 study period, a loss that may account for the lower *T. wasselli* abundance. In 2003-2004, *Scoletoma tenuis* was the second most numerically abundant organism over all habitat types and was among the top five dominant organisms found in open water habitats. There were no significant differences in abundances of *S. tenuis* in tidal creek versus open water habitats in the current study ($p = 0.282$).

SCECAP uses a single multi-metric benthic index of biological integrity (B-IBI) to distinguish between degraded and undegraded environments in southeastern estuaries (Van Dolah *et al*., 1999). A number of metrics (i.e., abundance, number of species, and abundance of sensitive taxa) have been integrated into the B-IBI in order to summarize benthic community condition in coastal habitats. About 70% of South Carolina's open water and 71% of tidal creek habitat sampled in 2003-2004 had a healthy benthic community (Table 3.4.3). There has been an apparent decrease in the amount of habitat supporting healthy benthic communities (ie., coding as good benthic condition) since the initial 1999-2000 survey (open water = 16% decline, tidal creek = 13% decline; Van Dolah *et al*., 2002a, 2004a). The amount of South Carolina's coastal habitat that supported benthic communities having some evidence of possible degradation (ie., coding as fair benthic condition) was approximately 22% in open water habitat and 21% in tidal creek habitats. Both habitat types have shown an increase in the percentage of habitat having only fair benthic community condition since the 1999-2000 study (Table 3.4.3). Approximately 8% of the coastal open water and tidal creek habitat had a poor benthic community condition, which represents an approximate increase by 6% in open water habitat and 4% in tidal creek habitat since the inception of the program.

Table 3.4.3. Percent of habitat with B-IBI values indicating good (undegraded), fair (marginally degraded), or poor (degraded) benthic conditions.

	Percent of Habitat B-IBI					
	Open Water			Tidal Creek		
Study Period	Good	Fair	Poor	Good	Fair	Poor
1999-2000	86	12	2	84	12	4
2001-2002	83	14	3	69	27	4
2003-2004	70	22	8	71	21	8

When evaluating B-IBI scores on a yearly basis, there is clearly a trend of decreasing percentage of coastal habitat which supports healthy benthic communities in South Carolina (Figure 3.4.7), with associated increases in the percentages of coastal habitats which have fair and poor benthic community condition. While we didn't observe similar trends in water quality or sediment quality conditions over the course of the study, there has been an increase in ERM-Q (see section 3.3) in coastal areas. The contribution of rising contaminant levels to the decreasing B-IBI is unclear, particularly considering the concomitant changes in salinity during this time.

Finfish and Crustacean Communities

South Carolina estuaries support a diverse array of fish and crustaceans that are dependent on estuarine habitats for food and shelter (Joseph, 1973; Mann, 1982; Nelson *et al*., 1991). Estuaries represent a naturally stressful environment due to broad fluctuations in physical conditions (temperature, salinity, etc) and biological pressures such as predation and competition with other species. In addition, anthropogenic stressors such as recreational and commercial fishing, boating activity, upland development, storm water inputs, and habitat modifications are all placing additional pressures on South Carolina's essential estuarine habitats. Changes to these coastal ecosystems will ultimately lead to changes in the fish and crustacean communities that are dependent upon them (Monaco *et al*., 1992).

Community Composition:

A total of 14,912 organisms representing 72 species were collected by trawl during the 2003-2004 survey (data online). Mean faunal density across all stations varied from four to 4,790 individuals per hectare (individuals/ha) with an overall average of 714 individuals/ha. The mean density in tidal creeks (1040 individuals/ha) was more than twice the mean density in open water habitats (388 individuals/ha), a statistically significant difference ($p < 0.001$). The trend of higher mean faunal densities in tidal creek

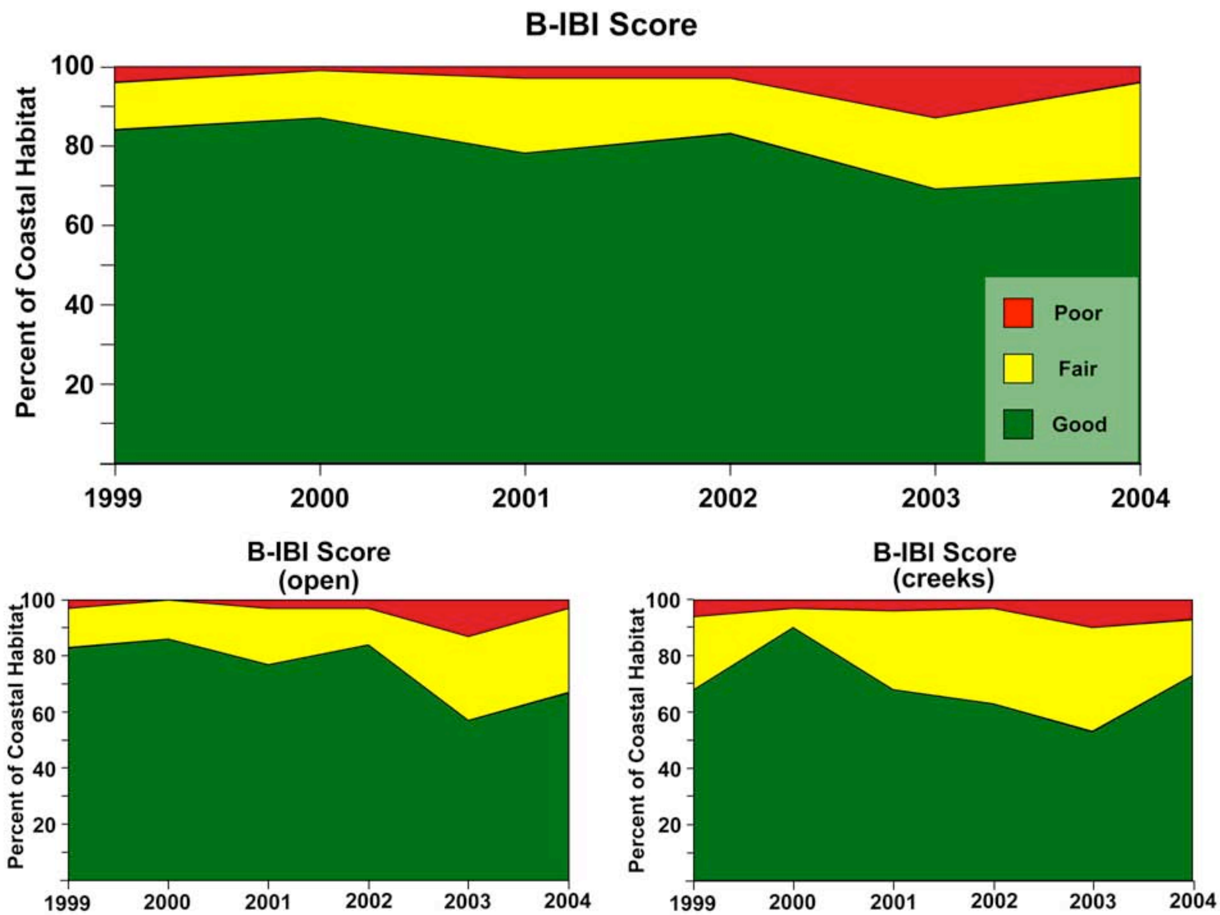


Figure 3.4.7. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the benthic index of biological integrity (B-IBI) values compared on an annual basis when tidal creek and open water habitats are combined and for tidal creek and open water habitats considered separately.

stations compared to open water stations has been observed in all three of the survey periods evaluated by SCECAP to date (Van Dolah *et al*., 2002a, 2004a).

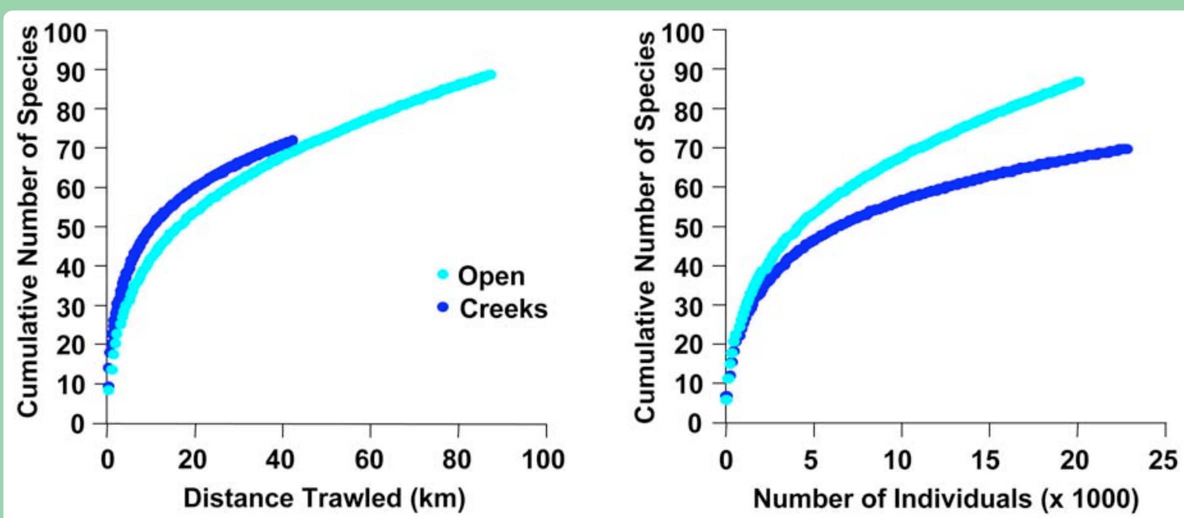
The average number of species collected across all stations was 5.9 and varied from 1 to 15 per trawl. Evenness values (J') averaged 0.66 and varied from 0.00 to 1.00, and overall community diversity (H') averaged 1.62 and varied from 0.00 to 2.96. The mean number of species per trawl was slightly higher in tidal creek habitat than in open water habitats (open water = 5.5, tidal creek = 6.4; p = 0.084), but J' (open water = 0.68, tidal creek = 0.65; p = 0.516) and H' (open water = 1.58, tidal creek = 1.67; p = 0.502) were similar. Similar trends were observed for both species numbers and diversity in previous survey periods (Van Dolah *et al*., 2002a, 2004a). While the number of species appears to be greater in tidal creek habitats, it is actually likely to be much greater in open water habitats (Box 3.4.3). Trawls in tidal creeks initially catch more species because fish and crustaceans occur at much higher densities there. However, open water habitats ultimately support more species, likely due to their proximity to the higher salinity open ocean and greater diversity of habitat types. This highlights the different roles filled by these habitats. Productive tidal creek habitats provide forage and nursery habitat for high-density populations of fish and crustaceans, while open water habitats serve as reservoirs of biodiversity.

The 50 most numerically abundant taxa comprised 99.8% of the overall abundance across all stations and included 23 recreationally and/or commercially important species (Table 3.4.4). The five most numerically abundant species were white and brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), pinfish (*Lagodon*

Box 3.4.3 Large Finfish and Crustacean Biodiversity

How many species of large demersal finfish and crustaceans use South Carolina's estuarine environments?

Answering this question requires the application of species-area or species accumulation curves, a technique that examines how rapidly the total number of species captured accumulates as one makes more collections. The graphic below shows the total number of species captured by trawling as a function of the total distance trawled and the total number of individual organisms captured. Notice that because finfish and crustaceans occur at much higher densities in tidal creeks, the number of species caught increases rapidly with trawling effort. However, with further trawling effort, the number of new species caught slows much more than in open water habitats. In open water habitats, the number of new species accumulates more slowly than in tidal creeks at first, but even after having trawled for approximately 90 km, the number of new species is still increasing. By extending these lines out until they become horizontal (to the point at which new species are no longer being captured with additional sampling effort), the total number of species using each habitat can be predicted. Applying this technique, South Carolina's tidal creek habitats are predicted to support approximately 89 large finfish and crustacean species while open water habitat are predicted to support approximately 138.



Species accumulation curves for all six years of SCECAP monitoring.

rhomboides), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). These recreationally and/or commercially important species accounted for 80% of all fish and crustaceans captured. Three of the five most numerically dominant taxa collected in 2003-2004 (*L. setiferus, F. aztecus, L. xanthurus*) were also among the five dominant taxa collected in both previous survey periods (Van Dolah *et al*., 2002a, 2004a). In open water habitats, the five most numerically abundant taxa were white shrimp, Atlantic croaker, brown shrimp, spot, and weakfish (*Cynoscion regalis*), species that comprised approximately 72% of the total abundance of fish and crustaceans in this habitat. In tidal creek habitats, the five most numerically abundant taxa were white shrimp, pinfish, brown shrimp, spot, and brief squid (*Lolliguncula brevis*), species that comprised more than 87% of the total abundance in this habitat. White shrimp, the most abundant species in both open water and tidal creek habitats, were found in significantly greater numbers in tidal creek habitats ($p = 0.005$) than in open water habitats. With the exception of

Table 3.4.4. The mean densities (number per hectare) and percent occurrence of the 50 numerically most abundant taxa collected by trawl in tidal creek and open water habitats during 2003-2004. Recreationally-important species are shown in bold text.

		Open Water		Tidal Creek	
Species Name	Common Name	Mean Abundance (#/hectare)	Percent of Stations Where Present	Mean Abundance (#/hectare)	Percent of Stations Where Present
Litopenaeus setiferus	**White shrimp**	125.4	48	569.9	67
Farfantepenaeus aztecus	**Brown shrimp**	42.7	62	97.6	73
Lagodon rhomboides	**Pinfish**	21.0	23	104.5	58
Leiostomus xanthurus	**Spot**	36.2	67	83.1	75
Micropogonias undulatus	**Atlantic croaker**	47.8	50	9.4	43
Lolliguncula brevis	Brief squid	16.1	50	38.2	55
Bairdiella chrysoura	**Silver perch**	3.5	32	33.2	53
Cynoscion regalis	**Weakfish**	27.6	37	3.3	22
Stellifer lanceolatus	Star drum	23.0	28	7.6	13
Anchoa mitchilli	Bay anchovy	6.6	33	17.9	48
Trinectes maculatus	Hogchoker	5.9	42	13.3	42
Callinectes sapidus	**Blue crab**	3.0	27	14.5	43
Chaetodipterus faber	**Atlantic spadefish**	2.6	23	6.8	25
Selene vomer	Lookdown	6.0	23	3.3	22
Callinectes similis	Lesser blue crab	2.8	15	3.7	25
Ictalurus furcatus	**Blue catfish**	0.7	7	5.6	8
Orthopristis chrysoptera	Pigfish	1.3	15	5.0	25
Chloroscombrus chrysurus	Atlantic bumper	2.6	12	1.2	3
Gerreidae	Mojarras	1.0	8	2.3	10
Opsanus tau	Oyster toadfish	0.2	5	2.3	15
Paralichthys lethostigma	**Southern flounder**	0.5	12	1.7	18
Prionotus scitulus	Leopard searobin	2.0	8	0.1	2
Chilomycterus schoepfi	Striped burrfish	0.2	7	1.7	17
Centropristis striata	**Black sea bass**	0.2	3	1.7	3
Stephanolepis hispidus	Planehead filefish	0.6	7	0.9	7
Paralichthys dentatus	**Summer flounder**	0.8	10	0.6	7
Menticirrhus americanus	**Southern kingfish**	0.5	8	0.7	7
Brevoortia tyrannus	Atlantic menhaden	0.2	3	1.1	7
Selene setapinnis	Atlantic moonfish	1.2	2	0.0	0
Dasyatis sabina	Atlantic stingray	0.4	7	0.7	7
Symphurus plagiusa	Blackcheek tonguefish	0.4	10	0.6	8
Citharichthys spilopterus	Bay whiff	0.2	5	0.7	10
Gymnura micrura	Smooth butterfly ray	0.1	3	0.7	7
Menticirrhus sp.	**Kingfish**	0.5	8	0.2	3
Peprilus alepidotus	Harvestfish	0.7	5	0.0	0
Lepisosteus osseus	longnose gar	0.0	0	0.6	7
Prionotus tribulus	Bighead searobin	0.6	10	0.0	0
Anchoa hepsetus	Striped anchovy	0.4	8	0.1	2
Farfantepenaeus duorarum	**Brown-spotted shrimp**	0.1	2	0.5	3
Etropus crossotus	Fringed flounder	0.0	0	0.5	5
Mugil cephalus	**Striped mullet**	0.0	0	0.5	5
Synodus foetens	Inshore lizardfish	0.0	0	0.5	5
Centropristis philadelphica	Rock sea bass	0.0	0	0.5	5
Dasyatis sayi	Bluntnose stingray	0.4	5	0.0	0
Rhizoprionodon terraenovae	**Atlantic sharpnose shark**	0.3	7	0.1	2
Cynoscion nebulosus	**Spotted sea trout**	0.0	0	0.4	3
Archosargus probatocephalus	**Sheephead**	0.1	2	0.2	2
Scomberomorus maculatus	**Spanish mackerel**	0.1	3	0.1	2
Ictalurus catus	**White catfish**	0.0	0	0.2	2
Lepomis sp.		0.0	0	0.2	2
Pomatomus saltatrix	**Bluefish**	0.0	0	0.2	2

Atlantic croaker, the abundance of the other dominant organisms was also significantly greater in tidal creek habitats than in open water habitats.

There are currently no formal indices of estuarine habitat condition applicable to the southeastern US using large crustacean and fish communities. However, using percentiles, areas supporting unusually low crustacean and fish densities and biodiversities can be identified. The 10th, 25th and 50th percentiles of mean densities, mean species number, and mean community diversity (H') in open water and tidal creek habitats are presented in Table 3.4.5. Two open water stations and two tidal creek stations (RO036057, RO046070, RT042064, and RT042070) fell below the 10th percentile for each of these metrics. Based on the overall integrated measure of habitat quality (Appendix 2), only RT042070 was coded as not having good habitat quality. Located on a tributary of the Cooper River upriver from Grove Creek in the Charleston area, this station had only a fair overall habitat quality score, with a good water quality score, but fair condition for sediment quality and poor for benthic community condition.

Recreationally and Commercially Important Species:

Recreationally and commercially important fish and crustaceans collected during the 2003-2004 sampling season included 23 species and accounted for 88% of the total abundance of organisms in the trawls (Table 3.4.4; data online). During the 1999-2000 and 2001-2002 survey periods, these taxa comprised 75% and 84% of the total abundance, respectively. Recreationally and commercially important taxa were significantly more abundant in tidal creek habitats (average = 935 indiv/ha) than in open water habitats (314 indiv/ha) during the 2003-2004 survey period ($p = 0.013$). A significantly greater number of recreationally or commercially important species also were found in tidal creek habitats (4.0 species per trawl) than in open water habitats (3.2 species/trawl; $p = 0.005$) even though the trawls in tidal creeks were half the length of those in open water habitats (0.25 km vs. 0.50 km).

The mean densities of selected species over the six-year period from 1999 to 2004 do not suggest any consistent pattern of increase or decline across the various species assessed (Figure 3.4.8). In open water habitats, white shrimp, weakfish, and spot showed slightly increasing abundance over time. In tidal creek habitats, white shrimp also showed a slight increase in abundance while weakfish and brown shrimp showed slight decreases in abundance.

Since SCECAP started in 1999, the program has provided a source of fisheries-independent monitoring for species which are not otherwise monitored by SCDNR. These include several commercially and recreationally important fish species such as spot, weakfish, and Atlantic croaker. Changes in bag and size limits have been advocated recently for several species including weakfish. Our knowledge of the distributions and population dynamics of several of these species remains incomplete and the data collected by this monitoring program could help to fill some of the existing gaps. The SCECAP database also provides critical information on the distributions and population structures of many fish and invertebrates

Table 3.4.5. Mean values and the 10th, 25th, and 50th percentiles for density (individuals/hectare), number of species and overall community diversity (H') values for open water and tidal creek habitats.

	Density		Number of Species		Overall Community Diversity (H')	
	Open	Tidal	Open	Tidal	Open	Tidal
Mean	389	1042	5.6	6.5	1.58	1.67
10th percentile	36	186	2.5	3.0	0.72	0.78
25th percentile	73	288	3.0	4.9	1.13	1.20
50th percentile	197	485	5.3	6.8	1.55	1.73

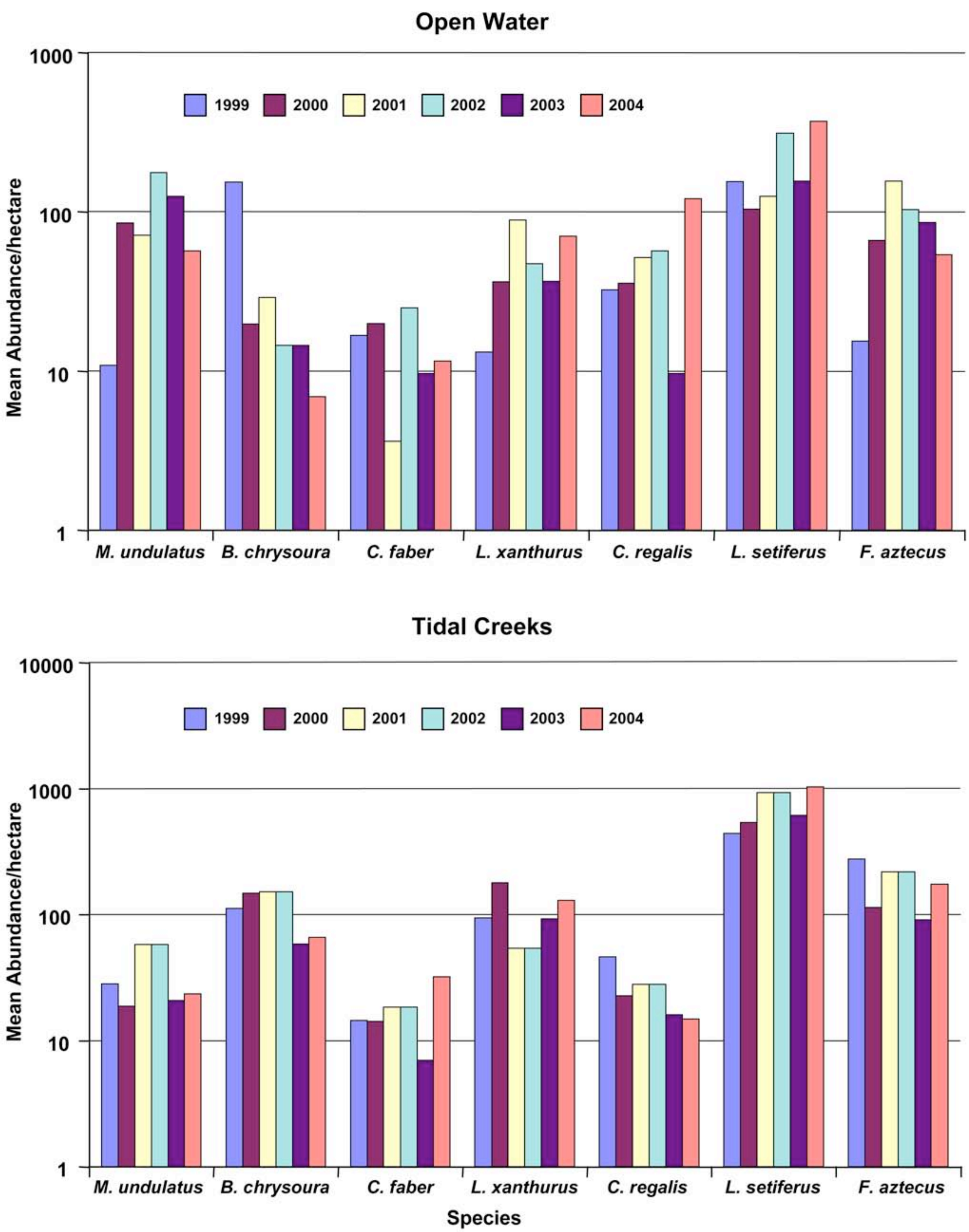


Figure 3.4.8 Mean abundances (number per hectare) of common commercially and recreationally-important fish and crustacean species in open water and tidal creek habitats between 1999 and 2004.

*Table 3.4.6 Priority Species for the South Carolina State Comprehensive Wildlife Conservation Plan that have been captured during the six years of SCECAP monitoring. * = species infrequently caught.*

Marine Fish	Marine Invertebrates
Atlantic Spadefish	Brief Squid
Bay Anchovy	Horseshoe Crab*
Atlantic Croaker	Lined Seahorse*
Kingfish	Stone Crab*
Southern Flounder	
Spot	
Tonguefish	
Crevalle Jack*	
Mummichog*	
Sheepshead*	
Striped Mullet*	

identified as "Priority Species" for the South Carolina State Comprehensive Wildlife Conservation Plan (Table 3.4.6). While other SCDNR programs provide data on some of these species, SCECAP remains the only source of information on many others.

Body Size:

The estuaries of South Carolina serve as nursery habitats for many estuarine and coastal species. Juvenile spot, Atlantic croaker, and penaeid shrimp often numerically dominate tidal creek habitats. An analysis of the length of spot, brown shrimp, and white shrimp from 2001-2004 generally supports this trend. Spot and white shrimp, two of the three most abundant species in both habitats, were significantly larger in open water habitats vs. tidal creek habitats ($p=0.002$ and $p<0.001$ respectively). The size of brown shrimp was not significantly different between the habitat types. However, brown shrimp spawn earlier in the year than do white shrimp, so by the time this program begins sampling (late June), the brown shrimp are fairly large and have begun to move from tidal creek habitats into open water habitats.

Tissue Contaminants:

Human activities can result in the release of contaminants (PAHs, heavy metals, PCBs and pesticides) into estuaries. These chemical compounds can accumulate in estuarine fauna through direct contact with contaminated water and sediments and can be transferred up the food chain from prey to predator. In order to evaluate the level of contamination of estuarine fauna in South Carolina, SCECAP monitors the levels of 93 different contaminants in the tissues of trawled fish. While these values do not necessarily indicate direct human health threats, they do provide a useful index of what contaminants are entering the estuarine food web and where estuarine fauna are most likely exposed to them. In general, the fish collected by SCECAP are small (mean = 10 cm in length), so whole fish are processed rather than just the fillets. The whole body contaminant data collected by SCECAP is an environmental measure of contaminants in fish tissues and should not be directly compared to edible tissue concentrations (fillets only) often used as a measure of risk to humans. Use of whole fish may underestimate the concentration of some contaminants (e.g., mercury) in edible tissue, but provides a better estimate of overall contaminant concentration in the organism.

For the 2003 and 2004 sampling periods, fish tissues were collected at 48 and 35 stations, respectively. The target species were spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*), both benthic feeders with similar life histories in South Carolina estuaries. Between 2000 and 2003, other species such as pinfish were substituted when the target species were not collected in sufficient quantities. During 2004, tissue samples were taken only for spot and croaker, thus fewer stations had tissue contaminant data in 2004 relative to previous years.

Overall, the level of contamination of young spot and croaker in South Carolina estuaries is low (data online). Therefore, statistical analyses were performed on "total" values, the sums of all the analytes within each class (metals, PAHs, PCBs, and pesticides) for each station. Total metals in fish tissues showed a general trend of higher values in tidal creek habitats than in open water habitats, but total PAHs, total PCBs and total pesticides showed no significant difference between habitat types. Analyses of total contaminant values by year suggested only minimal changes from one year to the next and no generally increasing or decreasing trends across years. When comparing total contaminant values by station, only one station

(RT042079) had a maximum value for total metals that was greater than total metal values at stations found in previous survey periods (2000-2002).

Stations where individual contaminant concentrations in fish tissue exceeded the 90th percentile for tissue contaminants in the 2000-2002 SCECAP data set were also evaluated to identify potentially contaminated habitats. The number of contaminants that exceeded the 90th percentile were counted at each station, and stations were ranked based on the number of exceedences. Due to changes in the method detection limits for PAHs, these contaminants were left out of this analysis. Exceedence values ranged from zero (no contaminants exceeded their respective 90th percentile value) to 14 exceedences at station RT042194 in the upper Ashley River. Of the six random stations that had 7 or more exceedences, four of the stations were in suburban or urbanized rivers: RO036054 in Winyah Bay, RT042194 and RT032046 in the Ashley River, and RO046087 in the Beaufort River. The distribution of contaminated fish tissue in 2003-2004 was similar to previous survey periods where the most highly contaminated fish were caught in suburban and urban rivers such as the Ashley River and the upper part of Winyah Bay.

3.5 Incidence of Litter

Solid waste products, or litter, represent an inevitable consequence of human presence in natural systems. As development and recreational and commercial activities continue to increase in South Carolina's coastal zone, the amount of litter entering our estuaries, flushing into the open ocean, and washing up on beaches is expected to increase.

During 2003 and 2004, litter was visible in 13% of the state's tidal creek habitat and 3% of state's open water habitat. This represented a decrease since the 2001-2002 survey period (during which 20% of tidal creek and 8% of open water habitat had litter), but litter remained elevated well above the 1999-2000 levels (2% of tidal creek and 3% of open water habitat). Generally, the greater percentages of tidal creek sites having litter relative to open water sites likely reflects the closer proximity of tidal creeks to human populations as well as the presence of shoreline, vegetation and oyster reefs that can retain litter within the viewing distance of the survey crews. The reduction in litter over the previous survey period may reflect the flushing of litter out of our estuaries by increased freshwater inflow or just normal variability among survey periods. Considering the year-to-year variability, additional monitoring will be necessary to determine long term trends in litter.

3.6. Integrated Measures of South Carolina's Estuarine Habitat Quality

SCECAP is unique compared to most state and federal monitoring programs because it combines integrated measures of water quality, sediment quality, and biological condition into an overall measure of habitat quality at each site and for the entire coastal zone within its coverage area. Multi-metric measures provide a more reliable assessment than any single measure or group of measures representing only one component of the habitat. For example, poor or fair water quality based on state standards or historical data may not result in any clear evidence of impaired biotic communities. Many of South Carolina's state water quality standards are intentionally conservative to be protective and some contraventions of these standards are not severe enough to result in biological impairment. Similarly, fair or poor sediment quality may not result in degraded biotic condition because the organisms are either not directly exposed to the sediments (e.g., phytoplankton, fish) or because the contaminants are not readily bioavailable to the organisms. When two or more of the three measures (e.g., water quality, sediment quality, or biotic condition) are only fair or poor, there is increased certainty that the habitat may be limiting. While several studies have use a "triad" approach to measuring bottom sediment quality (e.g., Chapman, 1990; Chapman *et al.*, 1991), very few programs have been established elsewhere that use a more holistic approach that includes water quality variables. The USEPA National Coastal Assessment Program is the most successful federal program to use an approach similar to SCECAP, although the habitat metrics and method of integrating those metrics are very different (USEPA, 2001, 2004).

The overall index of habitat quality currently used by SCECAP is described by Van Dolah *et al.* (2004a, available online). This index weights each of the three components equally (i.e., water quality, sediment quality, and benthic IBI scores). A site is considered to have poor habitat quality if two or more of the components score as poor, or if one component scores as poor and the other two score only fair. A site is considered to have fair habitat quality if two or more of the habitat quality components score as fair or only one component scores as poor. A site is considered to have good habitat quality if all three components score as good or if only one of the components scores no worse than fair.

Using this approach, approximately 80% of South Carolina's open water habitat and 77% of the state's tidal creek habitat were considered to have good overall habitat quality during the 2003-2004 survey (Figure 3.6.1). Approximately 18% of the state's open water habitat and 20% of the state's tidal creek habitat were considered to have fair overall habitat quality, and only 2% and 3% of the state's open water and tidal creek habitat, respectively, were considered to have poor overall habitat quality. The overall habitat quality scores for each of the stations sampled in 2003 and 2004 are presented in Appendix 2 along with the integrated water quality, integrated sediment quality, and B-IBI scores and their component parameter scores.

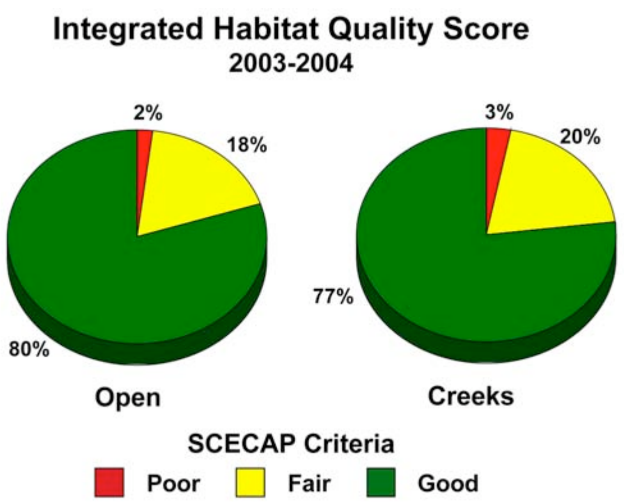


Figure 3.6.1. Estimated percentage of South Carolina's estuarine tidal creek and open water habitat that is in good, fair, or poor condition using an average of water, sediment, and biological quality scores developed for the SCECAP monitoring effort.

The proportion of the state's estuarine habitat that was considered to be either fair or poor was similar (within 1%) to that observed in the 2001-2002 survey. Fifteen of the tidal creek stations possessed fair to poor water quality scores while only seven open water stations possessed fair and none possessed poor water quality scores (Appendix 2). Additionally, there were comparable numbers of sites in each habitat with fair sediment quality (neither habitat had stations with poor sediment quality) and with fair or poor benthic community condition measures. In the 2001-2002 survey, tidal creeks had a higher percentage of sites with degraded sediment quality compared to open water sites (Van Dolah *et al*., 2004a), but a similar trend was not observed during this survey.

The 2003-2004 array of stations is presented in Figure 3.6.2 – 3.6.4 with each station color-coded based on its overall integrated habitat quality score. No open water stations scored as poor. Only one tidal creek site had an overall poor rating during the 2003-2004 survey, and was located near Middleton Gardens in the Ashley River (RT042194). This site had poor water quality due to very high nutrients (TN and TP) and high fecal coliform bacteria. Sediment quality at this same site scored as only fair, and the Benthic IBI scored as poor. This latter component may be an artifact of the very low salinity of this site because the database used for developing the B-IBI is not as robust at salinities less than 18ppt.

Seven of the 12 sites (58%) sampled in the northern portion of the state during 2003-2004 scored as only fair in overall habitat quality, with the remaining sites (42%) scoring as good in overall habitat quality (Figure 3.6.2). Four of the fair sites were located in the Winyah Bay estuarine system and the other three fair sites were located in the Santee River system. Winyah Bay has generally had a significant proportion of stations that code as fair or poor in previous surveys (Figure 3.6.5), most likely due to the proximity of industrial and urban development. It is less clear why the majority of the Santee River sites only receive a fair rating as there were no consistent problems among the stations. However, this drainage system occasionally receives large water inputs from upland via releases from the dams upstream, and a substantial amount of the estuarine portion of the Santee River has been impounded to attract waterfowl.

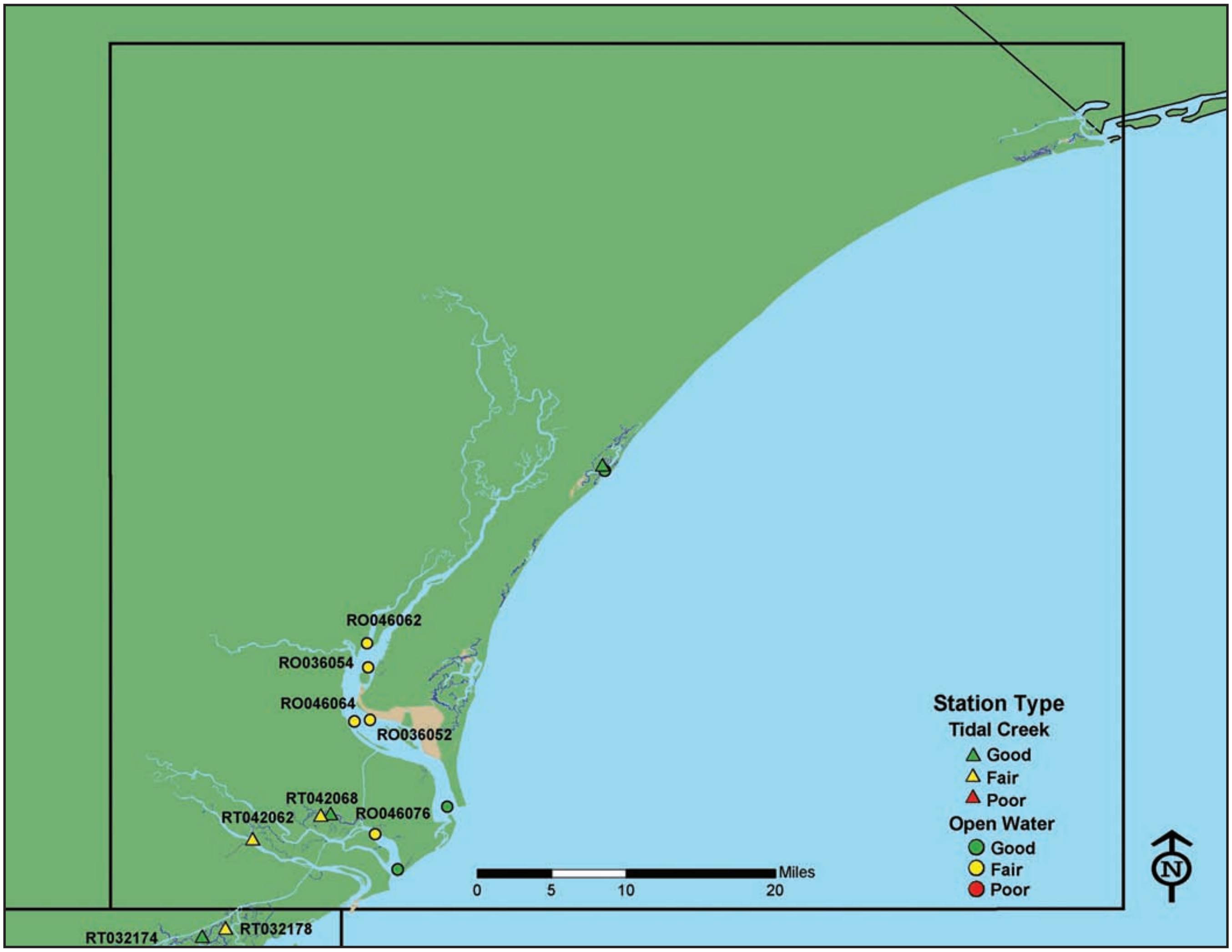


Figure 3.6.2. Distribution of open water and tidal creek stations sampled in the northern portion of the state during 2003-2004 that had an integrated habitat quality score of good, fair, or poor based on an integrated measure of water quality, sediment quality, and biotic condition.

Of the 42 randomly located sites sampled in the central portion of the state's coastal zone, eight (19%) scored as fair, one site (RT042194) scored as poor and the rest (79%) scored as good in overall habitat quality (Figure 3.6.3). The poor site and six of the fair sites were located in the Charleston Harbor estuary or adjacent Stono River; four of those were in tidal creek habitats. All of the impaired sites in the Charleston Harbor estuary were located in the upper reaches of the Ashley, Cooper and Wando Rivers. In previous surveys, the majority of stations showing some impairment generally were located closer to the harbor basin in the lower reaches of these rivers. The Ashley River continues to show evidence of water quality problems, especially with respect to nutrients and fecal coliform bacteria. Both of the sites sampled in the upper Ashley River also had poor benthic communities, which may be reflective of the very low salinity conditions at those sites. The sites in the Cooper and Wando Rivers that scored as fair in overall habitat quality all had good water quality, but only fair sediment quality and fair to poor benthic community condition. Greater strain will be placed on these already impaired systems as the Charleston metropolitan area continues to grow along the upper reaches of the Ashley, Cooper and Wando Rivers.

In the southern portion of the state, only 12 of the 68 randomly selected sites (18%) were fair in overall habitat quality, and the remaining sites had

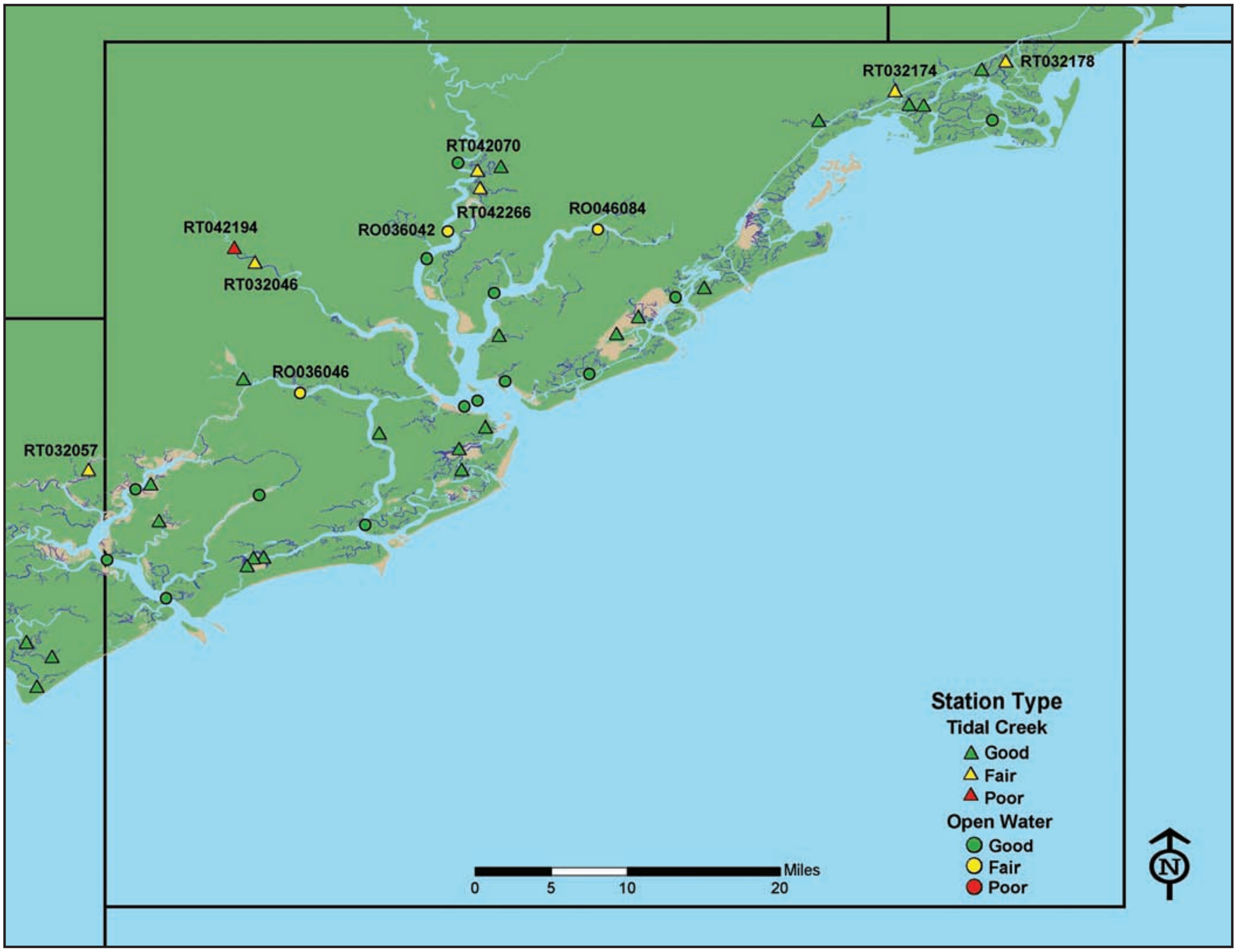


Figure 3.6.3. Distribution of open water and tidal creek stations sampled in the central portion of the state during 2003-2004 that had an integrated habitat quality score of good, fair, or poor based on an integrated measure of water quality, sediment quality, and biotic condition.

good overall habitat quality (Figure 3.6.4). This is very comparable to conditions observed in previous surveys, which indicated generally better overall habitat quality than in the more developed central and northern estuaries. The majority of the sites that showed some impairment were located in tidal creeks. Five of the stations with fair habitat quality were located in the Ashepoo, Combahee, Edisto (ACE) River Basin (RT032031, RT032035, RT032177, RO036043, RO046071), one was located in Dewees Creek located off the North Edisto River (RT032057), two were located in creeks behind Fripp Island (RT032188, RT032056), one behind St. Philips Island (RO046074), one was located in the Savannah River (RO046061), and the remaining two were located in the New River (RT042063) and Cooper River west of Calibogue Sound (RO036053) in the southern part of the state. There was no consistent reason for the partial impairment of these sites, although many had evidence of high nutrient concentrations and/or high fecal coliform bacterial levels. Many of these sites were in areas that drain agricultural lands.

One of the advantages of the SCECAP sampling protocol is that stations are relocated each year on a random basis. Since the inception of the program, this has resulted in the assessment of a large array of stations (> 350) state-wide that provide some insight as to where the greatest threats in estuarine habitat quality exist. Considering the distribution of only

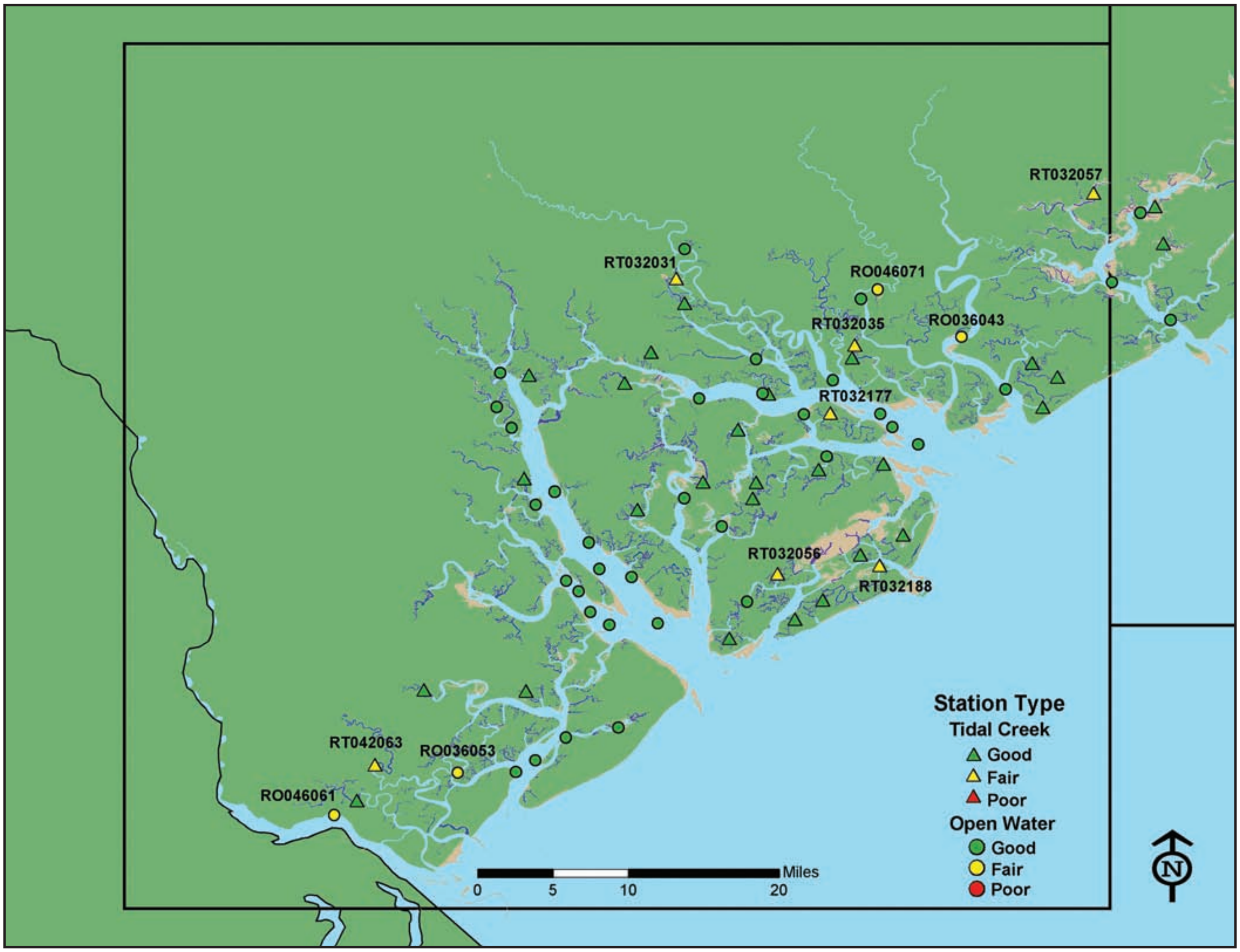


Figure 3.6.4. Distribution of open water and tidal creek stations sampled in the southern portion of the state during 2003-2004 that had an integrated habitat quality score of good, fair, or poor based on an integrated measure of water quality, sediment quality, and biotic condition.

those stations that received either fair or poor scores, sites with a poor habitat quality rating were primarily located in Winyah Bay and the Charleston Harbor estuary, especially in the Ashley River (Figure 3.6.5). While only one site in the southern portion of the state had a poor score, there was a substantial number with only a fair habitat quality score, especially in the upper portions of the ACE Basin. SCECAP staff plan to further evaluate potential causes for impairment in the ACE Basin, but a preliminary assessment of land use patterns suggests that much of the impairment may be due to proximity of agricultural activities.

The Ashepoo-Combahee-Edisto (ACE) Basin, a popular ecotourism destination in South Carolina, is surrounded by agricultural operations.

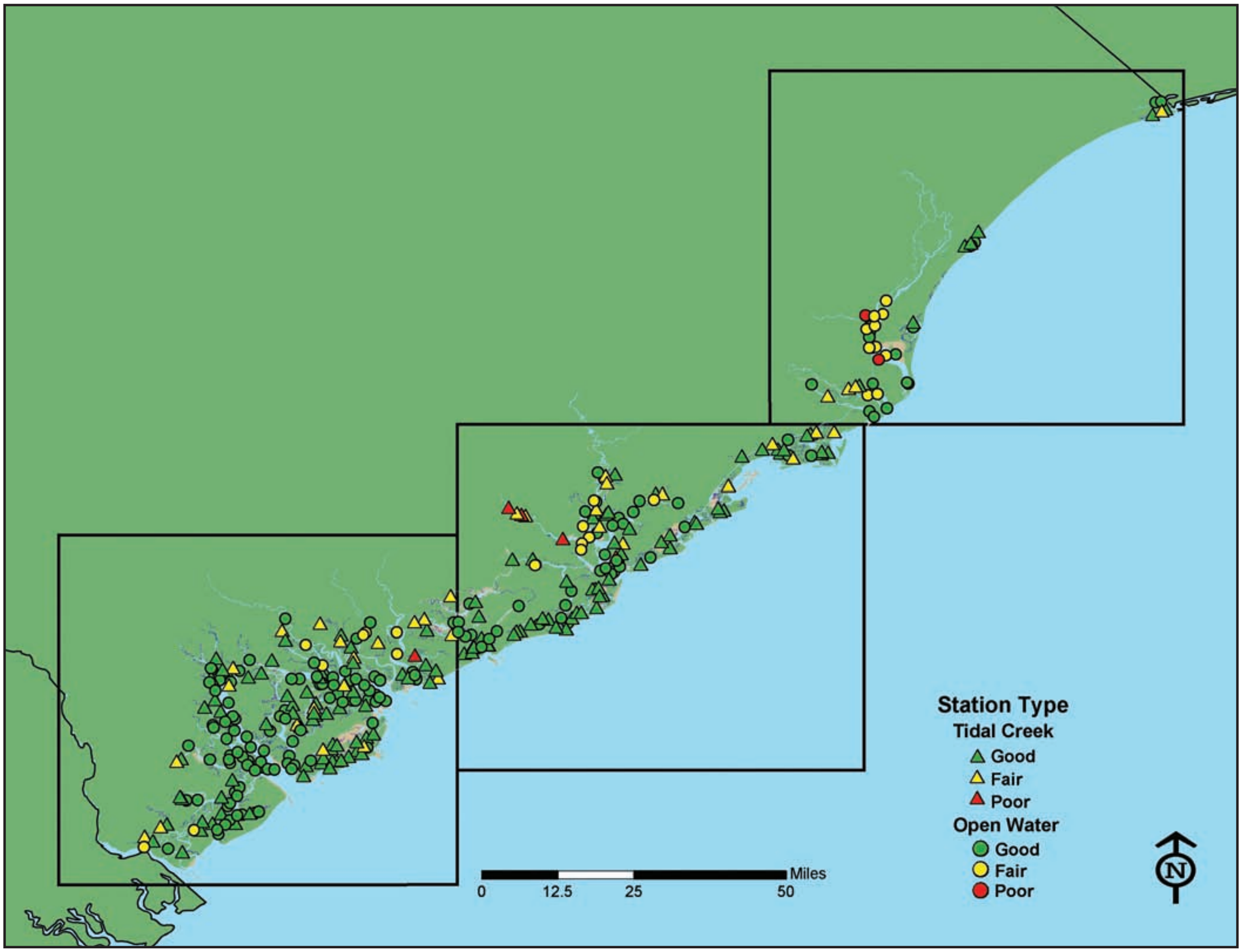


Figure 3.6.5. Distribution of open water and tidal stations sampled in South Carolina between 1999 and 2004 that had an integrated habitat quality score of good, fair, or poor based on an integrated measure of water quality, sediment quality, and biotic condition.

Figure 3.6.6 depicts the overall trend in habitat quality by year for both tidal creek and open water habitats combined, as well as for each habitat separately. As mentioned earlier in the report, tidal creek habitats represent only 17% of the overall estuarine habitat in the state and are therefore weighted less in the combined habitat assessment.

Since 2000, there has been a slight decrease in percentage of the state's estuarine habitat that is considered to be good (approximately 5%), although it should be noted that 1999 was comparable to the percentage in 2004. When evaluating overall habitat quality for open water habitat only, there is a greater decline of approximately 13% in the amount of good estuarine habitat from 1999 to 2004. This same pattern was not observed in tidal creeks, which showed relatively similar percentages of good tidal creek habitat from 1999-2003, and then an increase in 2004 (Figure 3.6.6). While none of these trends are statistically significant, it will be critical to continue monitoring overall habitat quality to determine whether the increasing impairment noted in open water habitat and all habitats combined poses a long-term threat to the health of our estuaries.

3.7 Future Program Activities

The SCECAP database has already provided a valuable resource that continues to be tapped by

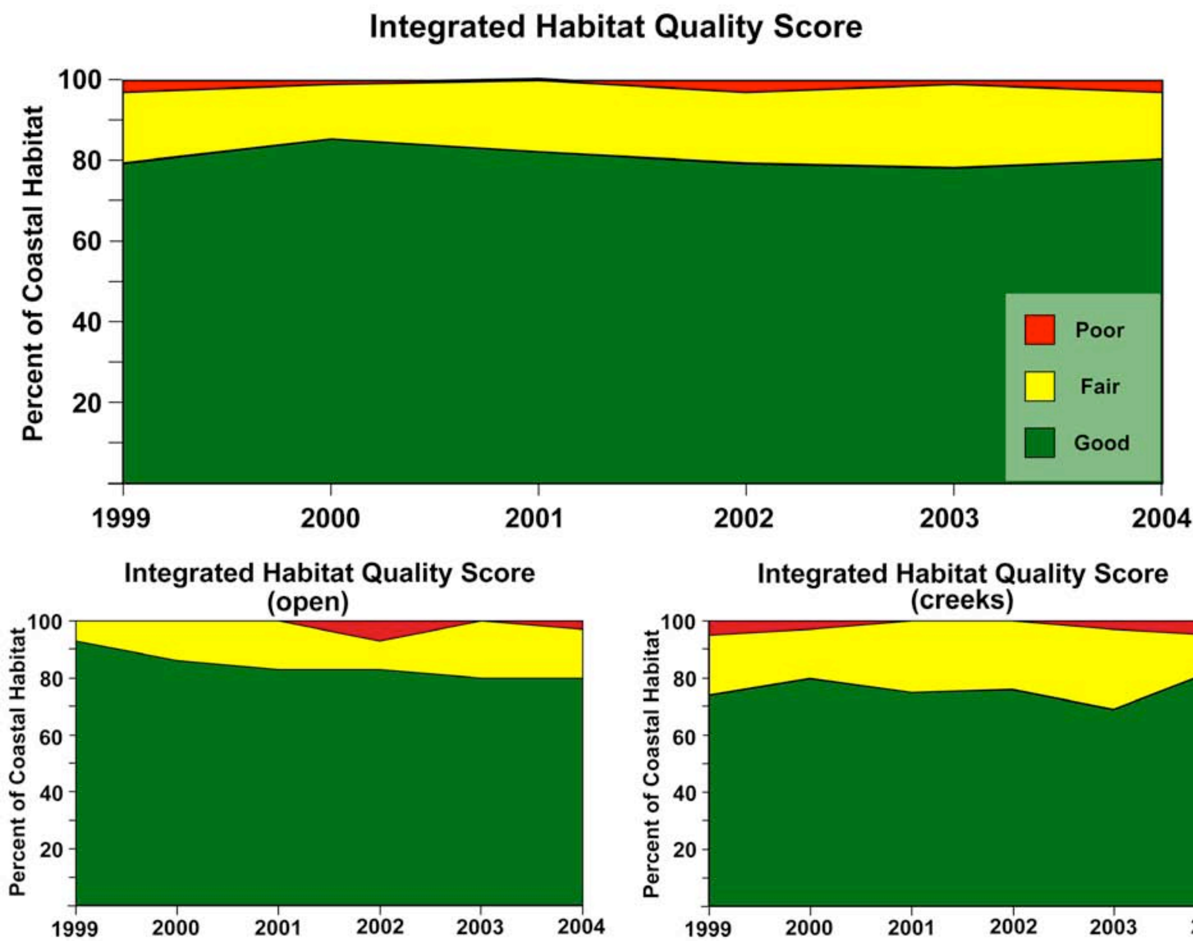


Figure 3.6.6. The proportion of South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated habitat quality score when tidal creek and open water habitats are combined and compared on an annual basis.

programs within the SCDNR as well as by other governmental agencies and non-profit organizations. For example, the NOAA Dolphin Survey and the NOAA Oceans and Human Health Initiative (OHHI) have mined the SCECAP database in order to relate estuarine environmental measures with dolphin health and land use characteristics, respectively. In 2002-2003, a multi-agency study was conducted for the Town of Bluffton to assess the existing health of the May River (Van Dolah *et al*., 2004b). That study utilized a comparable sampling approach and relied on existing SCECAP sampling to obtain data from relatively pristine estuarine locations sampled in the southern portion of the state for comparison as reference sites, thereby considerably reducing expenses for the Town of Bluffton. The Nature Conservancy is currently utilizing the SCECAP database to evaluate the condition and integrity of the Sewee-Santee-Winyah estuarine complex in order to develop a conservation action plan for the area. Additional analyses are also in progress using SCECAP and other databases to evaluate the relationships between land use patterns and estuarine habitat quality (Van Dolah *et al.,* in prep.) with the longer-term goal of developing models describing the interactions between human development and coastal ecosystems.

Funding for SCECAP through the USEPA is expected to be terminated in 2007. This will necessitate a major restructuring of the program with respect to environmental variables assessed and number of sites sampled per year, dependent on alternative funding sources. Given the growth in South Carolina's coastal zone and the likelihood that this will result in further degradation of our estuaries, it is imperative that the

SCDNR and SCDHEC maintain this cooperative program to identify trends in estuarine habitat quality. Only an adequate holistic monitoring program will allow us to detect these changes and subsequently act to reduce or avoid serious degradation of our coastal zone.

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Appendix 1. Summary of station locations and dates sampled in 2003 and 2004. Open water sites are designated as RO (random open water site) and tidal creek sites are designated as RT (random tidal creek site). Development codes: NDV = no development visible; R < 1 = residential development less than one km away; R > 1 = residential development greater than one km away; I < 1 = industrial development less than one km away; I > 1 = industrial development located greater than one km away.

SCECAP 2003 Water Quality
Station Information -- Open Water

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code*	Approximate Location
RO036031	Open	32.52635	80.84660	3.0	7/9/03	Jasper	R>1	Broad River near Old Seaboard Coastline Railroad
RO036032	Open	32.31651	80.77124	14.0	7/22/03	Beaufort	R>1	Chechessee River near Colleton River
RO036033	Open	32.37917	80.63374	4.1	6/25/03	Beaufort	R<1	Distant Island near Cowan Creek
RO036034	Open	32.28600	80.69524	7.9	6/25/03	Beaufort	R>1	Port Royal Sound southwest of Parris Island
RO036035	Open	32.49351	80.85025	2.4	7/9/03	Jasper	R>1	West Branch of Boyd Creek
RO036036	Open	32.29655	80.76009	4.6	7/22/03	Beaufort	R>1	Chechessee River north of Mackay Creek
RO036037	Open	32.53983	80.60097	4.6	7/16/03	Beaufort	R<1	Wimbee Creek southeast of South Wimbee Creek
RO036038	Open	32.15406	80.81312	7.6	7/23/03	Beaufort	R>1	Calibogue Sound northwest of Broad Creek
RO036039	Open	32.68064	80.23162	10.1	7/29/03	Charleston	R>1	Wadmalaw River south of Yonges Island
RO036040	Open	32.99130	79.92586	4.0	7/2/03	Berkeley	I<1	Cooper River near Flag Creek
RO036041	Open	32.67546	80.11437	2.7	7/29/03	Charleston	R<1	Bohicket Creek southwest of SC 700 Bridge
RO036042	Open	32.92578	79.93539	12.8	7/2/03	Berkeley	I<1	Cooper River near mouth of Goose Creek
RO036043	Open	32.56110	80.40351	3.7	8/12/03	Colleton	NDV	South Edisto River northeast of Fenwick Cut
RO036044	Open	32.78354	79.88120	1.0	7/1/03	Charleston	R<1	Charleston Harbor near Shem Creek
RO036046	Open	32.77223	80.07559	2.4	8/12/03	Charleston	R>1	Stono River near Seaboard Coastline Railroad
RO036047	Open	32.47410	80.46965	7.3	7/16/03	Beaufort	NDV	St. Helena Sound at Morgan River
RO036048	Open	32.75927	79.91965	4.9	7/1/03	Charleston	R<1	Charleston Harbor near James Island Yacht Club
RO036049	Open	32.64528	80.66974	5.8	7/8/03	Colleton	NDV	Combahee River northwest of Coosaw River
RO036050	Open	32.79052	79.80096	1.2	7/1/03	Charleston	R>1	ICWW at Little Goat Island
RO036052	Open	33.29015	79.26511	7.6	8/5/03	Georgetown	I>1	Winyah Bay west of Marsh Islands
RO036053	Open	32.14202	80.88748	3.4	7/23/03	Beaufort	NDV	Cooper River west of Calibogue Sound
RO036054	Open	33.34093	79.26710	0.3	8/5/03	Georgetown	I>1	Winyah Bay north of Rabbit/Hare Islands
RO036055	Open	32.51925	80.52688	5.5	7/16/03	Beaufort	NDV	Combahee River northwest of Coosaw River
RO036056	Open	32.17622	80.78387	1.5	7/22/03	Beaufort	R<1	Broak Creek near Calibogue Sound
RO036057	Open	32.36364	80.76163	7.3	8/19/03	Beaufort	NDV	Broad River northwest of Archer Creek
RO036058	Open	33.14487	79.23836	2.1	8/5/03	Georgetown	NDV	North Santee Bay
RO036059	Open	32.48635	80.55486	4.3	7/15/03	Beaufort	NDV	Parrot Creek south of Coosaw River
RO036060	Open	33.53214	79.03709	1.5	8/13/03	Georgetown	R<1	Murrells Inlet at Main Creek
RO036152	Open	32.32693	80.78334	9.1	7/22/03	Beaufort	R>1	Chechessee River at Colleton River
RO036153	Open	32.59761	80.50013	2.7	7/8/03	Colleton	NDV	Ashepoo River north of Ashepoo Coosaw cutoff

SCECAP 2003 Water Quality
Station Information -- Tidal Creeks

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code*	Approximate Location
RT032031	Creek	32.61710	80.67776	3.7	7/8/03	Beaufort	NDV	Wimbee Creek near headwaters
RT032032	Creek	32.11543	80.98472	4.6	7/23/03	Jasper	NDV	Wright River near Turn Bridge Landing
RT032033	Creek	32.43864	80.47837	1.5	7/15/03	Beaufort	R<1	Coffin Creek near Morgan River
RT032035	Creek	32.55318	80.50612	3.0	7/8/03	Colleton	NDV	Rock Creek near Ashepoo River
RT032039	Creek	32.42125	80.65188	3.4	6/25/03	Beaufort	R<1	Factory Creek near White Hall Landing
RT032040	Creek	33.04664	79.49731	3.0	8/6/03	Charleston	NDV	Long Creek northeast of Bull's Bay
RT032041	Creek	32.50603	80.58903	3.7	7/16/03	Beaufort	R>1	Tributary at east tip of Chisholm Island
RT032043	Creek	32.39520	80.71507	2.4	6/25/03	Beaufort	R>1	Tributary to Battery Creek north of SC 802 Bridge
RT032045	Creek	32.43321	80.54091	2.4	7/15/03	Beaufort	R>1	Eddings Point Creek southwest of Morgan River
RT032046	Creek	32.89688	80.11839	0.9	8/12/03	Charleston	R>1	Ashley River near Runnymede Plantation
RT032048	Creek	32.98748	79.88486	0.9	7/2/03	Berkeley	NDV	Grove Creek northeast of Flag Creek
RT032050	Creek	32.71955	79.92465	2.5	7/1/03	Charleston	R<1	Clark Sound south of Oyster Point
RT032052	Creek	33.19878	79.30353	2.1	8/5/03	Georgetown	NDV	Minim Creek northwest of Intracoastal Waterway
RT032055	Creek	32.61647	80.11040	2.7	7/30/03	Charleston	R>1	Kiawah River near mouth of Haulover Creek
RT032056	Creek	32.33380	80.58017	1.3	6/24/03	Beaufort	R<1	Scott Creek north of Station Creek Landing
RT032057	Creek	32.69939	80.27644	1.2	7/29/03	Charleston	R<1	Toogoodoo Creek northeast of Swinton Creek
RT032060	Creek	32.82877	79.77532	4.9	8/13/03	Charleston	R>1	DeWees Creek southwest of Gadonsville Landing
RT032172	Creek	32.37085	80.45966	2.4	6/24/03	Beaufort	NDV	Johnson Creek southeast of Hunting Island Lighthouse
RT032173	Creek	32.54620	80.70181	2.1	8/12/03	Beaufort	R<1	Tributary five miles northeast of Paige Point Landing
RT032174	Creek	33.05996	79.51060	2.4	8/6/03	Charleston	NDV	Tibwin Creek north of Intracoastal Waterway
RT032176	Creek	32.28996	80.56349	3.7	6/24/03	Beaufort	NDV	Moon Creek east of Trenchards Inlet
RT032177	Creek	32.48740	80.52969	4.0	7/15/03	Beaufort	NDV	Tributary to Bass Creek on north side of Morgan Island
RT032178	Creek	33.08765	79.40561	2.4	8/6/03	Charleston	NDV	Skrine Creek southeast of McClellanville
RT032179	Creek	32.42471	80.82378	1.2	7/9/03	Beaufort	NDV	Buzzard Island Creek north of Buzzard Island
RT032180	Creek	32.69936	79.92202	4.3	7/30/03	Charleston	NDV	First Sister Creek northeast of Folly River Landing
RT032181	Creek	32.22174	80.92003	2.1	8/19/03	Beaufort	R<1	May River southeast of Shellfish 19-19
RT032186	Creek	32.82690	79.88667	0.9	7/2/03	Charleston	I>1	Hobcaw Creek northeast of Remleys Point
RT032187	Creek	32.61570	80.11976	1.2	7/30/03	Charleston	R>1	Haulover Creek west of Seabrook Island
RT032188	Creek	32.34179	80.48209	0.3	6/24/03	Beaufort	NDV	Tributary one mile west of Russ Point Landing
RT032031	Creek	32.63255	80.12914	1.8	7/8/03	Beaufort	NDV	Tributary to Wimbee Creek near headwaters

SCECAP 2004 Water Quality
Station Information -- Open Water

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code*	Approximate Location
RO046061	Open	32.10156	81.00655	14.0	6/29/04	Jasper	I<1	Savannah River northwest of Fields Cut
RO046062	Open	33.36431	79.26796	1.8	8/3/04	Georgetown	I<1	Pee Dee River mouth southwest of US 17 Bridge
RO046063	Open	32.33037	80.72060	5.5	6/30/04	Beaufort	R<1	Broad River off Parris Island near Ballast Creek
RO046064	Open	33.28855	79.28068	3.0	8/3/04	Georgetown	R>1	Winyah Bay southeast of Belle Isle Gardens
RO046065	Open	32.51056	80.36112	6.7	7/28/04	Colleton	R>1	South Edisto River below St. Pierre Creek
RO046066	Open	32.76469	79.90708	4.6	8/10/04	Charleston	I>1	Charleston Harbor southeast of Shutes Folly Island
RO046067	Open	32.45750	80.44525	9.1	8/17/04	Beaufort	NDV	Middle of St. Helena Sound
RO046068	Open	32.64682	80.01353	1.2	8/11/04	Charleston	R>1	Stono River southwest of Green Creek
RO046069	Open	32.48676	80.48139	10.1	8/17/04	Beaufort	NDV	Mouth of Coosaw River at St. Helena Sound
RO046070	Open	32.89993	79.95551	5.5	7/8/04	Berkeley	I<1	Cooper River southwest of mouth of Goose Creek
RO046071	Open	32.60650	80.48409	8.0	8/17/04	Colleton	NDV	Ashepoo River south of S-15-26
RO046072	Open	32.86306	79.71918	2.4	8/10/04	Charleston	R>1	Toomer Creek mouth at Intracoastal Waterway
RO046073	Open	32.50661	80.59464	1.8	7/13/04	Beaufort	R>1	Coosaw River north of mouth of Lucy Point Creek
RO046074	Open	32.30670	80.60972	2.7	7/20/04	Beaufort	NDV	Station Creek near Trenchard's Inlet
RO046075	Open	32.41227	80.79443	10.1	7/21/04	Beaufort	R>1	Broad River northwest of SC 170
RO046076	Open	33.17894	79.26051	3.7	8/3/04	Georgetown	NDV	North Santee Bay southeast of Big Duck Creek
RO046077	Open	32.44577	80.53301	2.4	7/14/04	Beaufort	R<1	Eddings Point Creek southeast of Morgan River
RO046078	Open	33.03140	79.41844	2.7	8/18/04	Charleston	NDV	Romain River at mouth of Key Creek
RO046079	Open	32.50150	80.65541	3.4	7/13/04	Beaufort	R<1	Coosaw River southeast of Brickyard Creek
RO046080	Open	32.14271	80.83191	0.3	6/29/04	Beaufort	R<1	Calibogue Sound near Daufuskie Island
RO046081	Open	32.57750	80.20270	10.4	7/27/04	Charleston	NDV	North Edisto River southwest of Rockville
RO046082	Open	33.20562	79.19000	3.0	8/4/04	Georgetown	NDV	Winyah Bay southwest of Georgetown Lighthouse
RO046083	Open	32.61371	80.25887	7.0	7/27/04	Charleston	R>1	North Edisto River east of Steamboat Creek
RO046084	Open	32.92754	79.79272	1.8	7/8/04	Charleston	R<1	Wando River southeast of Wagner Creek Mouth
RO046085	Open	32.47346	80.83597	4.6	7/21/04	Jasper	NDV	Boyd Creek east of East and West Branch Creeks
RO046086	Open	32.33827	80.75161	8.8	6/30/04	Beaufort	NDV	Broad River opposite mouth of Archer Creek
RO046087	Open	32.40650	80.66989	6.4	7/13/04	Beaufort	R<1	Beaufort River off Spanish Point
RO046088	Open	32.18564	80.73343	1.5	6/29/04	Beaufort	R<1	Broad Creek northeast of Lighthouse Landing
RO046089	Open	32.39978	80.81268	4.9	7/21/04	Beaufort	R>1	Euhaw Creek southeast of Buzzard's Island Creek
RO046090	Open	32.28426	80.74212	11.0	6/30/04	Beaufort	R>1	Chechessee River northeast of Mackay Creek
RO046286	Open	32.86693	79.89157	5.8	7/8/04	Berkeley	I>1	Wando River near Ralston Creek

SCECAP 2004 Water Quality
Station Information -- Tidal Creeks

Station	Station Type	Latitude Decimal Degrees	Longitude Decimal Degrees	Station Depth (meters)	Date Sampled	County	Development Code*	Approximate Location
RT042061	Creek	32.52394	80.81931	3.0	7/21/04	Beaufort	NDV	South Haulover Creek southwest of Sheldon
RT042062	Creek	33.17431	79.37933	3.0	8/18/04	Georgetown	NDV	Sixmile Creek near South Santee River
RT042063	Creek	32.14970	80.96716	2.4	6/29/04	Beaufort	NDV	New River 8.5 miles southwest of Bluffton
RT042064	Creek	33.53772	79.03929	1.2	8/4/04	Georgetown	R>1	Tributary to Woodland Creek draining Weston Flat
RT042067	Creek	32.40618	80.60421	2.4	7/14/04	Beaufort	R<1	Tributary to Jenkins Creek southeast of Beaufort
RT042068	Creek	33.19761	79.31319	2.8	8/3/04	Georgetown	NDV	Minim Creek east of Bella Creek
RT042069	Creek	32.51632	80.72708	3.7	7/13/04	Beaufort	R<1	McCalley's Creek northwest of Beaufort
RT042070	Creek	32.98384	79.90726	2.4	7/8/04	Berkeley	I>1	Tributary to Cooper River upriver from Grove Creek
RT042072	Creek	32.74002	79.89969	1.5	7/7/04	Charleston	R<1	Tributary to Parrot Point Creek south of Fort Johnson
RT042073	Creek	32.60806	80.12601	1.5	8/11/04	Charleston	NDV	Kiawah River on the Flats
RT042074	Creek	32.35174	80.50061	1.8	7/20/04	Beaufort	NDV	Tributary to Story River west of Russ Point
RT042075	Creek	32.68615	80.21741	3.4	7/27/04	Charleston	I<1	Tributary to Wadmalaw River opposite Yonges Island
RT042076	Creek	32.87243	79.69184	3.4	8/10/04	Charleston	NDV	Santee Pass on Capers Island north of Isle of Palms
RT042077	Creek	32.65076	80.20953	2.4	7/27/04	Charleston	R<1	Tributary to Leadenwah Creek northwest of Rockville
RT042078	Creek	32.84480	79.75439	3.7	8/10/04	Charleston	R>1	Unnamed creek between Hamilin & Copahee Sounds
RT042079	Creek	32.54062	80.50860	5.2	8/17/04	Colleton	NDV	Rock Creek southwest of Ashepoo River
RT042080	Creek	32.30848	80.53677	1.5	7/20/04	Beaufort	NDV	Skull (Capers) Creek on Pritchards Island
RT042081	Creek	32.59336	80.66968	6.1	8/17/04	Beaufort	NDV	Wimbee Creek east southeast of Garden's Corner
RT042082	Creek	33.07978	79.42822	2.7	8/18/04	Charleston	NDV	Tributary to Dupre Creek on Jeremy Island
RT042083	Creek	32.47149	80.61813	1.2	7/14/04	Beaufort	R<1	Rock Springs Creek northeast of Beaufort
RT042084	Creek	33.03102	79.58321	2.7	8/18/04	Charleston	NDV	Awendaw Creek 2.2 miles east southeast of Awendaw
RT042086	Creek	32.27155	80.62669	1.5	7/20/04	Beaufort	NDV	Morse Island Creek near Port Royal Sound
RT042087	Creek	32.53563	80.33545	2.7	7/28/04	Charleston	R>1	Fishing Creek west southwest of Town of Edisto Island
RT042088	Creek	32.22076	80.82212	1.2	6/30/04	Beaufort	NDV	Tributary to Bass Creek southeast of Bluffton
RT042089	Creek	32.52220	80.31111	2.4	7/28/04	Charleston	R<1	Fishing Creek southwest of Town of Edisto Island
RT042191	Creek	32.49343	80.32539	2.4	7/28/04	Colleton	R<1	Scott Creek at Big Bay Creek near Edisto Island
RT042193	Creek	32.42098	80.60101	3.4	7/14/04	Beaufort	R<1	Jenkins Creek 2 miles northwest of Frogmore
RT042194	Creek	32.91016	80.13805	0.9	8/11/04	Dorchester	NDV	Tributary to Ashley River north of Middleton Gardens
RT042195	Creek	32.78598	80.12949	4.9	7/7/04	Charleston	NDV	Rantowles Creek at Seaboard Coastline Railroad
RT042196	Creek	32.73441	80.00051	1.5	7/7/04	Charleston	R>1	Tributary to Stono River on James Island near SC 700
RT042266	Creek	32.96704	79.90466	2.4	7/7/04	Berkeley	NDV	Flagg Creek off Cooper River in Charleston

Appendix 2. Summary of integrated measures of water quality, sediment quality, and biological condition (based on the Benthic Index of Biological Integrity), and the overall integrated measure of habitat quality using a combination of the three measures. Station location information is also provided. Scores coding as green represent good conditions, yellow represents fair conditions, and red indicates poor conditions. The actual values of the integrated scores are also shown to allow the reader to see where the values fall within the above general coding criteria. See text for further details on ranges of values representing good, fair, and poor for each integrated score.

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Station	Water Quality: Dissolved Oxygen	Water Quality: Fecal Coliform	Water Quality: pH	Water Quality: Total Nitrogen	Water Quality: Total Phosphorus	Water Quality: Chlorophyll-a	Water Quality: Integrated Score	Sediment Quality: Toxicity	Sediment Quality: Contaminants	Sediment Quality: Integrated Score	Biological Condition: Benthic IBI	Overall: Integrated Score	County	Location
RO036031							5			5	3	4.3	Jasper	Broad River near Old Seaboard Coastline Railroad
RO036032							5			5	5	5.0	Beaufort	Chechessee River near Colleton River
RO036033							5			5	5	5.0	Beaufort	Distant Island near Cowan Creek
RO036034							5			5	5	5.0	Beaufort	Port Royal Sound southwest of Parris Island
RO036035							3			5	5	4.3	Jasper	West Branch of Boyd Creek
RO036036							5			5	5	5.0	Beaufort	Chechessee River north of Mackay Creek
RO036037							5			5	5	5.0	Beaufort	Wimbee Creek southeast of South Wimbee Creek
RO036038							5			5	5	5.0	Beaufort	Calibogue Sound northwest of Broad Creek
RO036039							5			5	5	5.0	Charleston	Wadmalaw River south of Yonges Island
RO036040							5			3	5	4.3	Berkeley	Cooper River near Flag Creek
RO036041							5			5	3	4.3	Charleston	Bohicket Creek southwest of SC 700 Bridge
RO036042							5			3	1	3.0	Berkeley	Cooper River near mouth of Goose Creek
RO036043							5			5	1	3.7	Colleton	South Edisto River northeast of Fenwick Cut
RO036044							5			3	5	4.3	Charleston	Charleston Harbor near Shem Creek
RO036046							5			5	1	3.7	Charleston	Stono River near Seaboard Coastline Railroad
RO036047							5			5	5	5.0	Beaufort	St. Helena Sound at Morgan River
RO036048							5			3	5	4.3	Charleston	Charleston Harbor near James Island Yacht Club
RO036049							3			5	5	4.3	Colleton	Combahee River northwest of Coosaw River
RO036050							5			5	5	5.0	Charleston	ICWW at Little Goat Island
RO036052							3			3	3	3.0	Georgetown	Winyah Bay west of Marsh Islands
RO036053							5			3	3	3.7	Beaufort	Cooper River west of Calibogue Sound
RO036054							5			3	1	3.0	Georgetown	Winyah Bay north of Rabbit/Hare Islands
RO036055							5			5	3	4.3	Beaufort	Combahee River northwest of Coosaw River
RO036056							5			5	5	5.0	Beaufort	Broak Creek near Calibogue Sound
RO036057							5			5	5	5.0	Beaufort	Broad River northwest of Archer Creek
RO036058							5			5	5	5.0	Georgetown	North Santee Bay
RO036059							5			5	5	5.0	Beaufort	Parrot Creek south of Coosaw River
RO036060							5			5	5	5.0	Georgetown	Murrells Inlet at Main Creek
RO036152							5			5	5	5.0	Beaufort	Chechessee River at Colleton River
RO036153							3			5	5	4.3	Colleton	Ashepoo River north of Ashepoo Coosaw cutoff

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Station	Water Quality							Sediment Quality			Biological Condition	Overall	County	Location
	Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score	Toxicity	Contaminants	Integrated Score	Benthic IBI	Integrated Score		
RT032031							3			5	3	3.7	Beaufort	Wimbee Creek near headwaters
RT032032							5			5	3	4.3	Jasper	Wright River near Turn Bridge Landing
RT032033							5			5	3	4.3	Beaufort	Coffin Creek near Morgan River
RT032035							1			5	3	3.0	Colleton	Rock Creek near Ashepoo River
RT032039							5			3	5	4.3	Beaufort	Factory Creek near White Hall Landing
RT032040							5			5	5	5.0	Charleston	Long Creek northeast of Bull's Bay
RT032041							5			5	5	5.0	Beaufort	Tributary at east tip of Chisholm Island
RT032043			5				5			5	5	5.0	Beaufort	Tributary to Battery Creek north of SC 802 Bridge
RT032045							5			5	5	5.0	Beaufort	Eddings Point Creek southwest of Morgan River
RT032046							3			5	1	3.0	Charleston	Ashley River near Runnymede Plantation
RT032048							5			3	5	4.3	Berkeley	Grove Creek northeast of Flag Creek
RT032050							5			3	5	4.3	Charleston	Clark Sound south of Oyster Point
RT032052							5			3	5	4.3	Georgetown	Minim Creek northwest of Intracoastal Waterway
RT032055							5			5	5	5.0	Charleston	Kiawah River near mouth of Haulover Creek
RT032056							3			3	5	3.7	Beaufort	Scott Creek north of Station Creek Landing
RT032057							3			3	3	3.0	Charleston	Toogoodoo Creek northeast of Swinton Creek
RT032060							5			5	5	5.0	Charleston	DeWees Creek southwest of Gadonsville Landing
RT032172							5			3	5	4.3	Beaufort	Johnson Creek southeast of Hunting Island Lighthouse
RT032173							5			5	3	4.3	Beaufort	Tributary five miles northeast of Paige Point Landing
RT032174							3			3	1	2.3	Charleston	Tibwin Creek north of Intracoastal Waterway
RT032176							5			5	5	5.0	Beaufort	Moon Creek east of Trenchards Inlet
RT032177							5			3	3	3.7	Beaufort	Tributary to Bass Creek on north side of Morgan Island
RT032178							5			5	1	3.7	Charleston	Skrine Creek southeast of McClellanville
RT032179							5			5	5	5.0	Beaufort	Buzzard Island Creek north of Buzzard Island
RT032180							5			5	5	5.0	Charleston	First Sister Creek northeast of Folly River Landing
RT032181							5			5	5	5.0	Beaufort	May River southeast of Shellfish 19-19
RT032186							5			3	5	4.3	Charleston	Hobcaw Creek northeast of Remleys Point
RT032187							5			5	5	5.0	Charleston	Haulover Creek west of Seabrook Island
RT032188							3			5	3	3.7	Beaufort	Tributary one mile west of Russ Point Landing
RT032190							5			3	5	4.3	Charleston	Tributary to Wimbee Creek near headwaters

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Station	Water Quality							Sediment Quality			Biological Condition	Overall	County	Location
	Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score	Toxicity	Contaminants	Integrated Score	Benthic IBI	Integrated Score		
RO046061							5			3	3	3.7	Jasper	Savannah River northwest of Fields Cut
RO046062							3			3	1	2.3	Georgetown	Pee Dee River mouth southwest of US 17 Bridge
RO046063							5			5	3	4.3	Beaufort	Broad River off Parris Island near Ballast Creek
RO046064							3			3	5	3.7	Georgetown	Winyah Bay southeast of Belle Isle Gardens
RO046065							5			5	5	5.0	Colleton	South Edisto River below St. Pierre Creek
RO046066							5			3	5	4.3	Charleston	Charleston Harbor southeast of Shutes Folly Island
RO046067							5			5	5	5.0	Beaufort	Middle of St. Helena Sound
RO046068							5			5	5	5.0	Charleston	Stono River southwest of Green Creek
RO046069							5			5	3	4.3	Beaufort	Mouth of Coosaw River at St. Helena Sound
RO046070							5			5	5	5.0	Berkeley	Cooper River southwest of mouth of Goose Creek
RO046071							3			3	3	3.0	Colleton	Ashepoo River south of S-15-26
RO046072							5			5	5	5.0	Charleston	Toomer Creek mouth at Intracoastal Waterway
RO046073							5			5	5	5.0	Beaufort	Coosaw River north of mouth of Lucy Point Creek
RO046074							5			3	3	3.7	Beaufort	Station Creek near Trenchard's Inlet
RO046075							5			5	5	5.0	Beaufort	Broad River northwest of SC 170
RO046076							3			3	3	3.0	Georgetown	North Santee Bay southeast of Big Duck Creek
RO046077							5			5	5	5.0	Beaufort	Eddings Point Creek southeast of Morgan River
RO046078							5			3	5	4.3	Charleston	Romain River at mouth of Key Creek
RO046079							5			5	5	5.0	Beaufort	Coosaw River southeast of Brickyard Creek
RO046080							5			5	5	5.0	Beaufort	Calibogue Sound near Daufuskie Island
RO046081							5			5	5	5.0	Charleston	North Edisto River southwest of Rockville
RO046082							5			5	5	5.0	Georgetown	Winyah Bay southwest of Georgetown Lighthouse
RO046083							5			5	3	4.3	Charleston	North Edisto River east of Steamboat Creek
RO046084							5			3	3	3.7	Charleston	Wando River southeast of Wagner Creek Mouth
RO046085							5			5	5	5.0	Jasper	Boyd Creek east of East and West Branch Creeks
RO046086							5			5	5	5.0	Beaufort	Broad River opposite mouth of Archer Creek
RO046087							5			5	5	5.0	Beaufort	Beaufort River off Spanish Point
RO046088							5			5	5	5.0	Beaufort	Broad Creek northeast of Lighthouse Landing
RO046089							5			5	5	5.0	Beaufort	Euhaw Creek southeast of Buzzard's Island Creek
RO046090							5			5	5	5.0	Beaufort	Chechessee River northeast of Mackay Creek
SO046286							5			5	5	5.0	Berkeley	Wando River near Ralston Creek

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Station	Water Quality							Sediment Quality			Biological Condition	Overall	County	Location
	Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score	Toxicity	Contaminants	Integrated Score	Benthic IBI	Integrated Score		
RT042061							5			5	5	5.0	Beaufort	South Haulover Creek southwest of Sheldon
RT042062							5			3	3	3.7	Georgetown	Sixmile Creek near South Santee River
RT042063							3			3	5	3.7	Beaufort	New River 8.5 miles southwest of Bluffton
RT042064							5			5	5	5.0	Georgetown	Tributary to Woodland Creek draining Weston Flat
RT042067							3			5	5	4.3	Beaufort	Tributary to Jenkins Creek southeast of Beaufort
RT042068							5			3	1	3.0	Georgetown	Minim Creek east of Bella Creek
RT042069							5			5	5	5.0	Beaufort	McCalley's Creek northwest of Beaufort
RT042070							5			3	3	3.7	Berkeley	Tributary to Cooper River upriver from Grove Creek
RT042072							5			5	5	5.0	Charleston	Tributary to Parrot Point Creek south of Fort Johnson
RT042073							5			5	5	5.0	Charleston	Kiawah River on the Flats
RT042074							5			5	5	5.0	Beaufort	Tributary to Story River west of Russ Point
RT042075							5			5	3	4.3	Charleston	Tributary to Wadmalaw River opposite Yonges Island
RT042076							5			5	5	5.0	Charleston	Santee Pass on Capers Island north of Isle of Palms
RT042077							3			5	5	4.3	Charleston	Tributary to Leadenwah Creek northwest of Rockville
RT042078							5			5	5	5.0	Charleston	Unnamed creek between Hamilin & Copahee Sounds
RT042079							3			5	5	4.3	Colleton	Rock Creek southwest of Ashepoo River
RT042080							5			5	5	5.0	Beaufort	Skull (Capers) Creek on Pritchards Island
RT042081							3			5	5	4.3	Beaufort	Wimbee Creek east southeast of Garden's Corner
RT042082							5			5	5	5.0	Charleston	Tributary to Dupre Creek on Jeremy Island
RT042083							5			5	5	5.0	Beaufort	Rock Springs Creek northeast of Beaufort
RT042084							5			5	3	4.3	Charleston	Awendaw Creek 2.2 miles east southeast of Awendaw
RT042086							5			5	5	5.0	Beaufort	Morse Island Creek near Port Royal Sound
RT042087							5			5	5	5.0	Charleston	Fishing Creek west southwest of Town of Edisto Island
RT042088							5			5	5	5.0	Beaufort	Tributary to Bass Creek southeast of Bluffton
RT042089							3			5	5	4.3	Charleston	Fishing Creek southwest of Town of Edisto Island
RT042191							5			5	5	5.0	Colleton	Scott Creek at Big Bay Creek near Edisto Island
RT042193							5			3	5	4.3	Beaufort	Jenkins Creek 2 miles northwest of Frogmore
RT042194							1			3	1	1.7	Dorchester	Tributary to Ashley River north of Middleton Gardens
RT042195							5			5	5	5.0	Charleston	Rantowles Creek at Seaboard Coastline Railroad
RT042196							3			5	5	4.3	Charleston	Tributary to Stono River on James Island near SC 700
ST042266							5			3	3	3.7	Berkeley	Flagg Creek off Cooper River in Charleston

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